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Standards for U.S. Geological Survey Page-Size Illustrations

For Authors

Version 2.0, October 2015

U.S. Department of the Interior
U.S. Geological Survey

Standards

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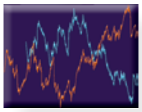

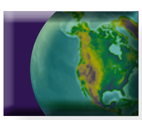

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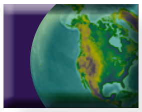

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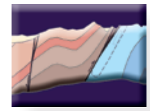

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Conversion Factors

[“Traditional publishing measurements are made in picas and points. There are 12 points per pica and 6 picas per inch. One pica is written as 1p0, where the zero indicates no additional points; 1½ picas is written as 1p6, which is equivalent to 18 points (12+6); 1¾ picas is written as 1p9; 2 picas is written as 2p0, and so forth” (U.S. Geological Survey, 2008, p. 3)]

Multiply	By	To obtain
	Units of measurement for type	
pica (pi)	12	point (pt)
inch (in.)	72	point (pt)
inch (in.)	6	pica (pi)

These standards refer to metric and English units. The modern U.S. metric system is the International System of Units, which is abbreviated as SI (from the French *Le Système International d’Unités*). U.S. customary units are informally called “English units.”

Ideally, all scientific reports published by the Federal Government would use SI units. See the background at http://ts.nist.gov/WeightsAndMeasures/Metric/Federal_Metric_Policy.cfm.

In practice, the USGS has been in a prolonged transition period since 1975 (Metric Conversion Law of 1975; P.L 94–169). Many reports include a combination of U.S. customary and SI units to report measurements exactly as taken from maps and equipment used.

Introduction

USGS Mission Statement

—The U.S. Geological Survey serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.

General Introduction and Overview

To accomplish the mission of the U.S. Geological Survey (USGS), data and information are collected, processed, analyzed, published, and distributed. To assist in the publishing of these data and information, this volume, titled "Standards for U.S. Geological Survey Page-Size Illustrations—*For Authors*," has been compiled to provide a comprehensive set of tools for effective graphic communication for subjects pertaining to biology, geography, geology, geospatial information, and water.

These standards are to be used for page-size illustrations—here defined as 11" by 17" or smaller—for formal-series publications only, not for open-file reports. The easily searchable Portable Document Format (PDF) renders unnecessary the need for an index.

While these standards present very little that is new, they pull material together between two covers for easy reference. Sources that were heavily drawn upon include

- Cartographic Technical Standards, Publications Division, USGS, 1978
- Standards for Illustrations in Reports of the USGS, Water Resources Division, 1987
- FGDC Digital Cartographic Standard for Geologic Map Symbolization, 2006
- Guidelines for Page-Size Illustrations for USGS Reports (Denver), 2008

This volume is divided into the following sections:

- Type Specifications and Fonts
- Line Specifications
- Colors, Patterns, and Symbols
- Explanations
- Graphs and Diagrams
- Maps
- Cross Sections, Stratigraphic Columnar Sections, and Correlation Charts
- Block Diagrams and Fence Diagrams
- Miscellaneous
- References

Four of the sections—explanations, graphs, maps, and cross sections—lead off with information-rich pages that provide general guidance and specifications. Please take the time to become familiar with these pages. Following these pages are many examples taken from a wide variety of reports from all regions and disciplines. Various layout options are presented.

As is the case with editors and text, if something in the illustration does not make sense to you, the illustrator, it probably will be unclear to the reader. Strive to make each page-size illustration "stand alone" by making sure that all symbology is described either in the explanation or figure caption or labeled in the figure itself. Create and design each illustration as close to final size as possible so when it is placed in the Adobe InDesign report template by publishing professionals, point sizes and lineweights will be correct. While each figure should be designed to "stand alone," each figure should also be consistent with all other figures within an individual report.

As illustrations were being formatted for these standards, attempts were made to adhere rigorously to the specifications as outlined in this volume. In some cases, however, smaller point sizes and thinner lineweights were substituted.

Remember that as an illustration is being created, good judgment and the discretion of the individual illustrator are required to make the illustration legible and aesthetically pleasing. Know that simplicity is often the most effective way to display complex ideas. Like writing well, creating good data graphics requires a combination of formal knowledge and artistic sensibility tempered by experience: a combination of "substance, statistics, and design" (Tufte, 2001, p. 51)

"As technology changes, three things will never change: good design, good aesthetics, and clear communication."
—Arthur Robinson

Type Specifications and Fonts

Introduction

As of June 2008, the Visual Identity System (VIS) policy on typefaces specifies that all USGS formal-series publications must use VIS-compliant fonts—Times New Roman and Univers Condensed. Both font families are now available in Open Type.

The VIS fonts that may be used for page-size illustrations are as follows:

Times New Roman	Univers 47 Condensed Light
Times New Roman Italic	*Univers 47 Condensed Light Oblique*
Times New Roman Bold	Univers 57 Condensed
Times New Roman Bold Italic	*Univers 57 Condensed Oblique*
	Univers 67 Condensed Bold
	Univers 67 Condensed Bold Oblique

The VIS fonts can be downloaded from the USGS Visual Identity System (VIS) Fonts Web site (available at http://communities.usgs.gov/blogs/vis/typography-and-color/typography/). See table 1 for a listing of typefaces and type sizes that may be used for features found in illustrations.

The Federal Geographic Data Committee (FGDC) created a font for geologic age symbols—the Federal Geographic Data Committee Geologic Age Symbol Font (FGDCGeoAge), a sans-serif font. The keystrokes for this specialized 25-character font can be found in table 2. The FGDCGeoAge Font can be downloaded from section 32 of the "FGDC Digital Cartographic Standard for Geologic Map Symbolization" (U.S. Geological Survey, 2006; hereinafter referred to as the FGDC Standard) (available at http://pubs.usgs.gov/tm/2006/11A02/).

The keystrokes for the USGS Hydro Font, a digitally created font used for symbology in water reports, are listed in tables 3 and 6. This symbol set can be loaded into Adobe Illustrator (see section on colors, patterns, and symbols). The USGS Hydro Font can be downloaded at http://internal.usgs.gov/publishing/toolboxes/graphic html.

To install the fonts on your computer, do the following:

Mac:
Place the USGSHydro.otf file under "USER'S HD/Library/Fonts/."

Win/UNIX:
Place the USGSHydro.otf file under "C:\Windows\Fonts\."

Once the FGDCGeoAge and USGS Hydro Fonts are installed on your computer, both can be accessed through the glyphs palette in Adobe Illustrator and Adobe InDesign. Under the "Type" menu, open the glyphs palette; select either the FGDCGeoAge or USGS Hydro Font. To insert a symbol into your document, use the text tool to create an insertion point (flashing I-beam), then double-click on the symbol in the glyphs palette you want to insert.

To make an illustration more visually appealing, the amount of leading (space between lines) and (or) kerning (space between letters) may need to be adjusted to fit the available space. The precise amount and method are left up to the discretion of the illustrator.

To make an illustration more visually appealing, the amount of leading (space between lines) and (or) kerning (space between letters) may need to be adjusted to fit the available space. The precise amount and method are left up to the discretion of the illustrator.

Type Specifications

Table 1. Visual Identity System (VIS)-compliant typefaces and type sizes suggested for use in page-size illustrations.

[Based on Federal Geographic Data Committee (FGDC) standards for a 1:24,000-scale map from "FGDC Digital Cartographic Standard for Geologic Map Symbolization" (available at http://pubs.usgs.gov/tm/2006/11A02/). Modified by the U.S. Geological Survey Illustrations Standards Team, October 2015. pt, point]

Item	Typeface	Type size (pt)	Remarks	Example of item[1]
Maps and cross sections				
Aquifer name	Univers 57 Condensed	8 or 9	Uppercase and lowercase	Floridan aquifer system
Base-map credit note	Univers 47 Condensed Light	7	Uppercase and lowercase	Base modified from U.S. Geological Survey 1:100,000-scale digital data
"Bend in section" note	Univers 47 Condensed Light	7	Uppercase	BEND IN SECTION
City name	Times New Roman	7 or 8	Uppercase and lowercase	Salt Lake City, St Louis
Contour number[2,3]	Univers 57 Condensed Oblique	7		*5,000 10,000*
Country name	Times New Roman Bold	9	Uppercase	**CANADA**
County name	Times New Roman Bold	7	Uppercase (if space allows)	**WALTON COUNTY**
Cross-section *y*-axis label	Times New Roman Bold Italic	8 or 9	Uppercase	***A–A′***
Elevation scale number	Univers 47 Condensed Light	7 or 8	Uppercase	SEA LEVEL 200 400 600
Dam name	Univers 57 Condensed Oblique	7	Uppercase	*BUFORD DAM*
Drainage basin and watershed name	Times New Roman	8 or 9	Uppercase and lowercase	Flint River Basin, Cullasaja watershed
Drainage feature (large lake, ocean)[4]	Times New Roman Italic	8	Uppercase	*LAKE MICHIGAN, ATLANTIC OCEAN*
Drainage feature (major)[4]	Times New Roman Italic	8 or 9	Uppercase and lowercase	*Ohio River, St Lawrence Seaway*
Drainage feature (minor)[4]	Times New Roman Italic	7	Uppercase and lowercase	*Jacks Creek, N Fork Broad River*
Fault name[5]	Univers 57 Condensed	7	Uppercase	BREVARD FAULT
Fold name (anticline, syncline, monocline)	Univers 57 Condensed	7	Uppercase and lowercase	Etam anticline, Parkersburg syncline, Defiance monocline
Gas and oil field	Univers 47 Condensed Light	7	Uppercase and lowercase	Gomex gas field, Prudhoe Bay oil field
General information	Univers 57 Condensed	7 or 8	Uppercase and lowercase	Uplands, Lowlands, Wetlands
Geographic coordinates[6] (latitude and longitude)	Univers 47 Condensed Light	7	Use degree symbols and primes	35°07'30" 81°30'
Geographic feature	Univers 57 Condensed	7	Uppercase and lowercase	Tybee Island, Appalachian Mountains
Geologic feature (major)	Univers 57 Condensed	7 or 8	Uppercase	SAN ANDREAS FAULT, APPALACHIAN BASIN
Geologic feature (minor)	Univers 57 Condensed	7	Uppercase and lowercase	Pitchstone Plateau, Pine Mountain thrust fault
Geologic formation name	Univers 57 Condensed	7 or 8	Uppercase and lowercase	Moretown Formation
Geologic age and formation (or lithology) symbol	FGDCGeoAge	7 or 8	Uppercase (age symbol); lowercase (formation or lithology symbol)	Є, Cambrian; ℙ, Pennsylvanian; OЄc, Conococheague Limestone (Lower Ordovician and Upper Cambrian)
Location map—"Area" label	Univers 57 Condensed	7 or 8	Upper and lowercase	Map area, Model area, Study area
Location map—State name	Times New Roman Bold	7 or 8	Uppercase	**MONTANA**
Mine name	Univers 67 Condensed Bold	7	Uppercase (if space allows)	**AMERICAN NETTIE MINE, CALLIOPE MINE**
Mining district name	Univers 57 Condensed	7 or 8	Uppercase	UNCOMPAHGRE MINING DISTRICT
Multipart figure label	Univers 67 Condensed Bold Oblique	8 or 9	Uppercase	***A, B, C***
National park name	Times New Roman Bold	7	Uppercase	**EVERGLADES NATIONAL PARK**
North/South/East/West[7]	Univers 47 Condensed Light	7	Uppercase	NORTH/SOUTH/EAST/WEST
Province boundary name	Univers 57 Condensed	7 or 8	Uppercase	PIEDMONT PROVINCE, VALLEY AND RIDGE PROVINCE, BASIN AND RANGE PROVINCE
Railroad name	Univers 57 Condensed Oblique	7	Uppercase	*COLORADO RAILROAD, SOUTHERN RAILROAD*
Rake scale number[3]	Univers 47 Condensed Light	7		0 5 10 1,000 10,000 MILES
Road name	Univers 57 Condensed Oblique	7	Uppercase	*MORELAND AVENUE, COX CEMETERY ROAD, ROUTE 66*
Sea level or datum	Univers 47 Condensed Light	7	Uppercase	NORTH AMERICAN VERTICAL DATUM OF 1988
Site identifier (drill hole, streamgage, well)	Univers 57 Condensed	7 or 8	Uppercase and (or) lowercase	SHN1 or rw206 (drill holes), 02336030 (streamgage), 07FF02 (well)
State capital name	Times New Roman	7	Uppercase	SANTE FE, COLUMBIA
State name[8]	Times New Roman Bold	8 or 9	Uppercase	**GEORGIA, NEW HAMPSHIRE**
State park name	Times New Roman Bold	7	Uppercase	**MYSTERY BAY STATE PARK**
Town name	Times New Roman	7	Uppercase and lowercase	Monroe, Social Circle
Township and range	Univers 47 Condensed Light	7	Uppercase	T. 32 N., R. 44 E.
"Vertical exaggeration" note	Univers 47 Condensed Light	7	Uppercase	VERTICAL EXAGGERATION ×10 IF >20×, USE "VERTICAL SCALE GREATLY EXAGGERATED"

Table 1. Visual Identity System (VIS)-compliant typefaces and type sizes suggested for use in page-size illustrations.—Continued

[Based on Federal Geographic Data Committee (FGDC) standards for a 1:24,000-scale map from "FGDC Digital Cartographic Standard for Geologic Map Symbolization" (available at http://pubs.usgs.gov/tm/2006/11A02/). Modified by the U.S. Geological Survey Illustrations Standards Team, October 2015. pt, point]

Item	Typeface	Type size (pt)	Remarks	Example of item[1]
Stratigraphic and correlation charts				
Body text (group name, formation name, or member name and unit of measurement)	Univers 57 Condensed	8	Uppercase and lowercase	Hamilton Group, Mahantango Formation, Rockwell Member
Column heading (series name, stratigraphic sequence name or unit name)	Univers 57 Condensed	9	Uppercase and lowercase	Era, Period, Epoch, Stage, Stratigraphic sequence, Sequence
Fossil name	Times New Roman Italic	8 or 9	Uppercase and lowercase	*Impagidinium* sp cf *strialatum, Bolboforma spinosa*
Unconformity name	Times New Roman	7	Uppercase	KNOX UNCONFORMITY, SUB-ZUNI UNCONFORMITY
Fossil plates				
Fossil name within plate title	Univers 57 Condensed Oblique	9	Uppercase and lowercase	Dinoflagellate Cysts *(Areosphaeridium diktyoplokus)* from the Chickahominy Formation
Identification number or letter of fossil	Univers 57 Condensed	10 or 12	Uppercase	1 2 A B
Plate title	Univers 67 Condensed Bold	9 or 10	Uppercase and lowercase	**Representative Mollusca from the Eastover and St. Marys Formations in the USGS–NASA Langley Core, Hampton, Va.**
Charts and graphs				
Explanations	See section on general information for explanations (p. 28)			
Axis caption	Univers 57 Condensed	8 or 9	Uppercase and lowercase	Water level, in feet above or below NAVD 88
Axis label	Univers 57 Condensed	7 or 8	Uppercase and lowercase	Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.

[1]Text can be used with varying percentages of black, as needed.

[2]Use commas in numbers greater than 999 except for topographic contour numbers, which never have commas (p. 77).

[3]Point size can vary if necessary.

[4]Can be 100 percent cyan for two-color figure or 100 percent cyan/ 60 percent magenta for four-color figure.

[5]Use uppercase (if space allows) for fault names; however, if uppercase and lowercase are used, the word "fault" is not capitalized.

[6]North arrow is not needed when latitude and longitude coordinates are given.

[7]Abbreviation allowed; use 8-point font size.

[8]Abbreviation allowed; use postal abbreviations if necessary.

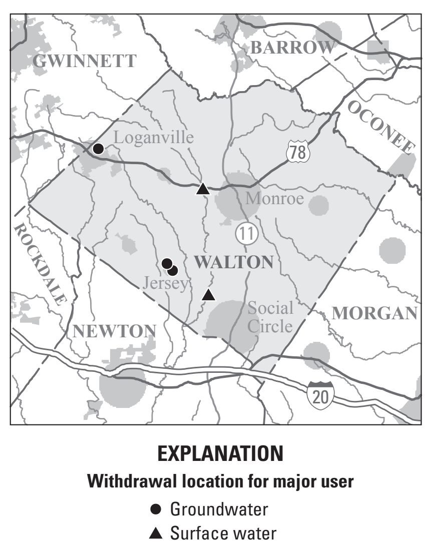


Figure 1. To aid legibility and highlight thematic data on a map, screen base-map information. Screen type and accompanying lines, which are not the prominent features on the page-size illustration. For example, screen roads, highways, and city names, if withdrawal locations are the prominent features. In general, begin screening with a value of 60 percent. Screening type more than 50 percent may make the type illegible.

Keystrokes for Special Fonts

Table 2. Keystrokes for the geologic age symbols from the FGDCGeoAge Font.

[The Federal Geographic Data Committee Geologic Age Symbol Font (FGDCGeoAge) can be downloaded from section 32 of the “FGDC Digital Cartographic Standard for Geologic Map Symbolization” (available at http://pubs.usgs.gov/tm/2006/11A02/). Reference number (Ref. no.) in the first column refers to the number of the symbol in the FGDC Standard. Stratigraphic age names have been changed for symbols 32.21, 32.22, 32.26, and 32.34. Other terms (32.23–32 25, 32.27–32.29, and 32.31–32.33, shown in gray) are no longer used so as to follow the most recently published chart by the U.S. Geological Survey Geologic Names Committee (2010)]

Ref. no.	Stratigraphic age	Subdivision type	Symbol	Keystrokes for FGDCGeoAge Font
32.1	Cenozoic	Era	Cz	{ (left curly bracket = shift–left square bracket).
32.2	Quaternary	Period	Q	No keyboard substitution needed.
32.3	Tertiary	Period	T	No keyboard substitution needed.
32.4	Neogene	Subperiod	N	No keyboard substitution needed.
32.5	Paleogene	Subperiod	Pɛ	: (colon = shift–semi-colon).
32.6	Mesozoic	Era	Mz	} (right curly bracket = shift–right square bracket).
32.7	Cretaceous	Period	K	No keyboard substitution needed.
32.8	Jurassic	Period	J	No keyboard substitution needed.
32.9	Triassic	Period	TR	^ (caret = shift–6).
32.10	Paleozoic	Era	Pz	| (vertical line = shift–backslash).
32.11	Permian	Period	P	No keyboard substitution needed.
32.12	Carboniferous	Period	C	No keyboard substitution needed.
32.13	Pennsylvanian	Subperiod	IP	* (asterisk = shift–8).
32.14	Mississippian	Subperiod	M	No keyboard substitution needed.
32.15	Devonian	Period	D	No keyboard substitution needed.
32.16	Silurian	Period	S	No keyboard substitution needed.
32.17	Ordovician	Period	O	No keyboard substitution needed.
32.18	Cambrian	Period	Ꞓ	_ (underscore = shift–hyphen).
32.19	Precambrian	Era	pꞒ	= (equal sign).
32.20	Proterozoic	Eon	Ᵽ	< (“less than” sign = shift–comma).
32.21	Neoproterozoic	Era	Z	No keyboard substitution needed.
32.22	Mesoproterozoic	Era	Y	No keyboard substitution needed.
32.23	Late Middle Proterozoic	Era	Y^3	` (accent grave).
32.24	Middle Middle Proterozoic	Era	Y^2	~ (shift–accent grave).
32.25	Early Middle Proterozoic	Era	Y^1	! (exclamation point = shift–1 [one]).
32.26	Paleoproterozoic	Era	X	No keyboard substitution needed.
32.27	Late Early Proterozoic	Era	X^3	@ (“at” sign = shift–2).
32.28	Middle Early Proterozoic	Era	X^2	# (pound sign = shift–3).
32.29	Early Early Proterozoic	Era	X^1	$ (dollar sign = shift–4).
32.30	Archean	Eon	A	No keyboard substitution needed.
32.31	Late Archean	Era	W	No keyboard substitution needed.
32.32	Middle Archean	Era	V	No keyboard substitution needed.
32.33	Early Archean	Era	U	No keyboard substitution needed.
32.34	Hadean	Eon	pA	> (“greater than” sign = shift–period).

Table 3. The USGS Hydro Font symbol descriptions, symbols, and corresponding keystrokes.

[The U.S. Geological Survey Hydro Font can be downloaded at http://internal.usgs.gov/publishing/toolboxes/graphic.html. Page numbers, shown in parentheses, indicate where the feature is found in the "FGDC Digital Cartographic Standard for Geologic Map Symbolization" (available at http://pubs.usgs.gov/tm/2006/11A02/)]

Description	Symbol	Keystrokes for USGS Hydro Font
Water well (p. A–26–1 to A–26–3)		
Type unspecified	○	Shift 1
Used for domestic-water supply	●	Shift 3
Used for stock-water supply	○	Shift 4
Used for irrigation-water supply	◎	Shift 5
Used for industrial-water supply	◉	Shift 7
Unused		Shift 0
Flowing artesian[1]		Shift 8
Nonflowing artesian[1]		Shift =
Recharge or waste-injection well[1]		-
Observation[1]		.
Observation, equipped with a recorder[1]		/
Abandoned[1]		0
Destroyed[1]		1
Test hole[1]		2
Capped[1]		3
Shut-in[1]		4
Dry hole—Water exploration[1]		5
Used for collection of water data[1]		6
Spring—Tail points in direction of flow (p. A–26–4)		
Type of use unspecified		7
Used for domestic-water supply		8
Used for stock-water supply		9
Used for irrigation-water supply		Shift ;
Used for industrial-water supply		;
Used for collection of water-quality data		Shift ,
Unused		Shift .
Thermal[2]		Shift /
Mineral[2]		Shift 2
Extinct[2]		Shift a
Streamgaging station (p. A–26–5)[3]		
Type of measurement unspecified	△	Shift b
Continuous record	▲	Shift c
Partial record		Shift d
Measurement station without a gage	△	Shift e
Discontinued		Shift f
Equipped with a telephone or radio[4]		Shift g
Peak-flow measurement station[4]		Shift h
Low-flow measurement station[4]		Shift i
Stage-measurement station[4]		Shift j
Continuous-record stage-measurement station		Shift m

Description	Symbol	Keystrokes for USGS Hydro Font
Surface-water-quality monitoring site (p. A–26–6)[5]		
Type of measurement unspecified	▽	Shift n
Active	▼	Shift o
Active, equipped with a monitor	▽	Shift p
Inactive		Shift q
Chemical measurement[6]		Shift r
Temperature measurement[6]		Shift s
Biological measurement[6]		Shift t
Sediment measurement[6]		Shift u
Hazardous waste site (p. A–20–1) (generally shown in red but may be shown in black)		
Type unspecified	▽	Shift n
Showing direction of surface-leachate flow from site		Shift w
Active (operating)	▼	Shift o
Inactive (closed)		Shift q
Clean-up activities are in progress		Shift v
Weather station (p. A–27–1)		
Type of measurement unspecified		a
Complete	◆	d
Equipped with a recorder[7]		b
Equipped with a telephone or radio[7]		c
Precipitation measurement		f
Evaporation measurement		g
Temperature measurement		h
Humidity measurement		i
Solar radiation measurement		j
Wind velocity measurement		k
Discontinued		l
Miscellaneous—Hydrologic (p. A–26–9)		
General direction of groundwater flow (accurately located)	➡ *or* ⇨	m *or* n
General direction of groundwater flow (approximately located)	→ *or* - - →	o *or* p

[1]Symbol may be used with any of the water well symbols shown above

[2]Symbol may be used with any of the spring symbols shown above

[3]Referred to as water gaging station in the FGDC Standard

[4]Symbol may be used with any of the streamgaging station symbols shown above

[5]Referred to as quality-of-water site in the FGDC Standard

[6]Symbol may be used with either of the active water-quality monitoring site symbols shown above

[7]Symbol may be used with either of the weather station symbols shown above

Line Specifications

Introduction

As words are the building blocks of sentences, lines are the building blocks of illustrations. Solid lines, dashed lines, dotted lines, black lines, blue lines, red lines, magenta lines—each line type and line color can be used (either alone or in combination) to clearly delineate any linear feature that needs to be shown in a page-size illustration. “Page-size” is defined as 11" by 17" or smaller.

Table 4 (p. 10) shows examples of specific linear features (river basin boundaries, geologic contacts, bathymetric contours, leaders) that are typically found in page-size illustrations. The features are shown with their corresponding lineweights, line symbols, and suggested colors.

Lineweight (or stroke) specifications follow, for the most part, those detailed in the FGDC Standard. FGDC page numbers—where cartographic specifications are described in minute detail—are shown in parentheses after many of the features listed in table 4. This table shows a subset of the line types available in the FGDC Standard, and the illustrator is encouraged to consult the FGDC Standard as needed.

“In previous standards, lineweights were specified in thousandths-of-an-inch, which corresponded to the widths of the engraving tools used to scribe the linework. Most lengths and distances also were given in inches” (U.S. Geological Survey, 2006, p. 29). In these standards, lineweights are given in points to correspond with the unit usually used in Adobe Illustrator and in millimeters to correspond with the unit used in the FGDC Standard.

In some illustrations, the color suggested for a linear feature might not “work” for the figure. If that is the case, consult the FGDC Standard for an acceptable alternative color or use your judgment to select a more appropriate color.

Sometimes it is necessary to screen lines to provide more legibility to overcrowded illustrations and maps. Screening is usually applied to black type. In general, begin screening with a value of 60 percent. Screen the lines and the accompanying type that are not the prominent features on the illustration or map. For example, screen rivers and river names, if roads, highways, and State park boundaries are the prominent features.

An understanding of cap and join styles and appearance attributes is useful. See pages 12 and 13 for a brief discussion of these concepts relative to Adobe Illustrator, including (1) how to change the cap or join of a line, (2) how to create a complex line with multiple attributes, (3) how to created dotted or dashed lines, and (4) which cap and join combination to use for a State boundary line or a river basin boundary line.

In some illustrations, the color suggested for a linear feature might not “work” for the figure. If that is the case, consult the FGDC Standard for an acceptable alternative color or use your judgment to select a more appropriate color.

Lineweights, Line Symbols, and Line Colors

Table 4. Lineweights, line symbols, and line colors for linear features shown in page-size illustrations.

[Based on Federal Geographic Data Committee (FGDC) standards for a 1:24,000-scale map from “FGDC Digital Cartographic Standard for Geologic Map Symbolization” (available at http://pubs.usgs.gov/tm/2006/11A02/); some lineweights were modified by the U.S. Geological Survey Illustrations Standards Team, October 2015. Page numbers, shown in parentheses, indicate where the linear feature is found in the FGDC Standard. mm, millimeter; C, cyan; M, magenta; Y, yellow; K, black]

Feature[1]	Lineweight[2]		Line symbol, in points[3]	Suggested color, when used
	points	mm	dash gap dash gap dash gap[4]	
Boundary—International (p. A–29–1)	1.1	0.375	18 2.4 5 2.4 5 2.4	
Boundary—State (p. A–29–1)	0.9	0.325	18 2.4 5 2.4 5 2.4	
Boundary—County (p. A–29–1)	0.7	0.25	18 2.4 5 2.4	
Boundary—City or town (p. A–29–1)	0.5	0.175	12 2.4	
Boundary—River basin or watershed (p. A–26–9)	1.3	0.46	21 4 0.1 4 0.1 4	
Boundary—River subbasin or watershed (p. A–26–9)	0.8	0.275	14 3 0.1 3 0.1 3	
Boundary—National or State park, monument, reservation, forest, grassland, wilderness area, or wildlife refuge (p. A–29–1)	0.5	0.175	18 3 0.7 3	
Coastline	0.5	0.175		2-color: 100% C 4-color: 100% C; 60% M
Contact (includes aquifers) (p. A–1–1 to A–1– 2)	0.4	0.15		
Accurately located				
Approximately located			10 2	
Inferred			4.2 2	
Concealed			1.4 2	
Continental Divide (p. A–29–1)	0.9	0.325	28 7	
Contour—Bathymetric (index) (p. A–30–2)	0.7	0.25		
Contour—Bathymetric (intermediate) (p. A–30–2)	0.4	0.15		
Contour—Bedrock (index) (p. A–26–7) (100% violet)	1.1	0.375		50% C; 90% M
Contour—Bedrock (intermediate) (p. A–26–7)	0.7	0.25		50% C; 90% M
Contour—Depression (p. 66 of these standards)				
Contour—Geophysical (index) (p. A–11–1)	0.9	0.325		
Contour—Geophysical (intermediate) (p. A–11–1)	0.6	0.2		
Contour—Potentiometric or water-table (index) (p. A–26–7)	1.1	0.375		2-color: 100% C 4-color: 100% C; 60% M
Contour—Potentiometric or water-table (intermediate) (p. A–26–7)	0.7	0.25		2-color: 100% C 4-color: 100% C; 60% M
Contour—Structure (index) (p. A–11–1) (100% red)	1.1	0.375		100% M; 90% Y
Contour—Structure (intermediate) (p. A–11–1)	0.7	0.25		100% M; 90% Y
Contour—Topographic (index) (p. A–30–1)	0.7	0.25		
Contour—Topographic (intermediate) (p. A–30–1)	0.4	0.15		
Contour—Water-quality-zone (index) (p. A–26–7) (100% green)	1.1	0.375		90% C; 85% Y

Table 4. Lineweights, line symbols, and line colors for linear features shown in page-size illustrations.—Continued

[Based on Federal Geographic Data Committee (FGDC) standards for a 1:24,000-scale map from "FGDC Digital Cartographic Standard for Geologic Map Symbolization" (available at http://pubs.usgs.gov/tm/2006/11A02/); some lineweights were modified by the U.S. Geological Survey Illustrations Standards Team, October 2015. Page numbers, shown in parentheses, indicate where the linear feature is found in the FGDC Standard. mm, millimeter; C, cyan; M, magenta; Y, yellow; K, black]

Feature[1]	Lineweight[2]		Line symbol, in points[3]	Suggested color, when used
	points	mm	dash gap dash gap dash gap[4]	
Contour—Water-quality-zone (intermediate) (p. A–26–7)	0.7	0.25		90% C; 85% Y
Dike (p. A–1–5) (100% red)	0.7	0.25		100% M; 90% Y
Drainage (intermittent) (p. A–30–4) Use two line appearance attributes (p. 12 of these standards)	0.5 0.5	0.175 0.175	Dash 9.4 7.25 Dots 0.04 1.81	100% K: 2-color: 100% C 4-color: 100% C; 60% M
Drainage (perennial) (p. A–30–4)	0.5	0.175		2-color: 100% C 4-color: 100% C; 60% M
Explanation box	0.4	0.15		
Fault (p. A–2–1 to A–2–16)	1.1	0.375		
Accurately located				
Approximately located			10 2	
Inferred			4.2 2	
Concealed			1.4 2	
Fold—Anticline (p. A–5–1 to A–5–5)	0.7	0.25		100% M
Fold—Syncline (p. A–5–6 to A–5–10)	0.7	0.25		100% M
Fold—Monocline (p. A–5–11 to A–5–12)	0.7	0.25		100% M
Groundwater divide (p. A–26–9)	1.9	0.675	0.1 3.5	
Leader[5]	0.3	0.106		
Line of equal, average, mean, or median (p. A–26–8)	1.1	0.375		
Line (trace) of section (p. A–31–1)	0.6	0.2		
Neatline	0.5	0.175		
Railroad Use two line appearance attributes (p. 12 of these standards)	4.0 0.3	1.4 0.106	Top dashed 0.3 8 Bottom solid	
Rake scale	0.5	0.175		
Route (Interstate, U.S. route, State route) (70% K)	0.9	0.325		
Road, street, or highway (p. A–28–1) (50% K)	0.7	0.25		
Route/road alternate Use two line appearance attributes (p. 12 of these standards)	0.7 1.4	0.25 0.5	Top white solid Bottom black solid	
State location map (p. A–34–1 to A–34–3)	If needed, State location maps can be downloaded from section 34 of the FGDC Standard (available at http://pubs.usgs.gov/tm/2006/11A02/).			
Ticks	0.5	0.175		
Township and range lines (p. A–31–1)	0.3	0.106		
Unconformity	0.4	0.15		

[1]For all contours (index and intermediate), break contour lines for contour values.

[2]Conversion factor for millimeters to points: 1 mm=2.83 points, then rounded to two significant figures.

[3]Can be used with varying percentages of black, as needed.

[4]For dashed lines, use round join and butt cap; for dashed-dotted lines, use round join and round cap.

[5]Preferably black, but may match the color of the text, if desired. Should be straight, not curved, without arrowheads.

Line Attributes

Cap Style and Join (Corner) Style of a Line

In Adobe Illustrator and Adobe InDesign, the cap style of a line is defined as the shape of the end of an open line. There are three styles: butt, round, and projecting. The end of a butt capped line is squared off. The end of a round capped line is a semicircle. The end of a projecting capped line is squared off but extends half a line width beyond the end of the line (fig. 2*A*).

The join style (now called "corner" in CS6) describes the shape where two line segments meet at an angle. There are three styles: miter, round, and bevel. In a miter join, the ends of adjacent line segments are continued to meet at a sharp point. In a round join, the join is a circle centered on a point where the adjacent line segments meet. In a bevel join, the join is squared off (figs. 2*A*, 3).

Different cap-join combinations change the appearance of a line. For example, rivers and roads, at certain scales, appear to be solid and continuous. However, "zooming in" makes it clear that these solid and continuous lines are oftentimes made up of many short line segments (fig. 2*B*). To give the appearance of a solid, continuous line, use round caps and round joins on these "slightly discontinuous" line segments (fig. 2*C*). Be aware that when the miter join is adjusted to "1," peaks flatten out.

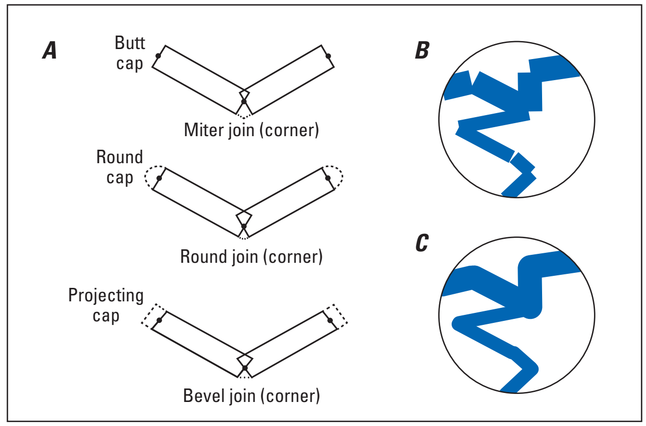


Figure 2. *A*, Visual representations of different combinations of cap and join styles available. *B*, Short, "slightly discontinuous" line segments. *C*, Continuous line generated by using round caps and round joins on the "slightly discontinuous" line segments shown in *B*.

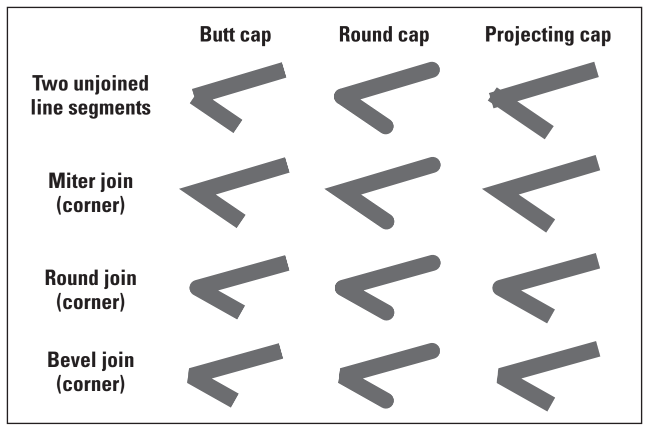


Figure 3. All possible combinations of cap and join styles (now called "corner" in CS6) applied to two intersecting, unjoined line segments. The top row shows the two unjoined line segments. The remaining rows show how these line segments can be connected to form a continuous line using the various joins available.

Appearance Panel

A complex line can be created by copying and pasting two lines with different attributes on top of each other. An alternative is to use the appearance panel in Illustrator to create multiple attributes for a single line. Appearance attributes include fill, stroke, transparency, and effects. As shown in figure 4, the intermittent stream symbol has been created by using two stroke attributes with different dash-gap values. For more information, go to http://helpx.adobe.com/illustrator/using/appearance-attributes.html.

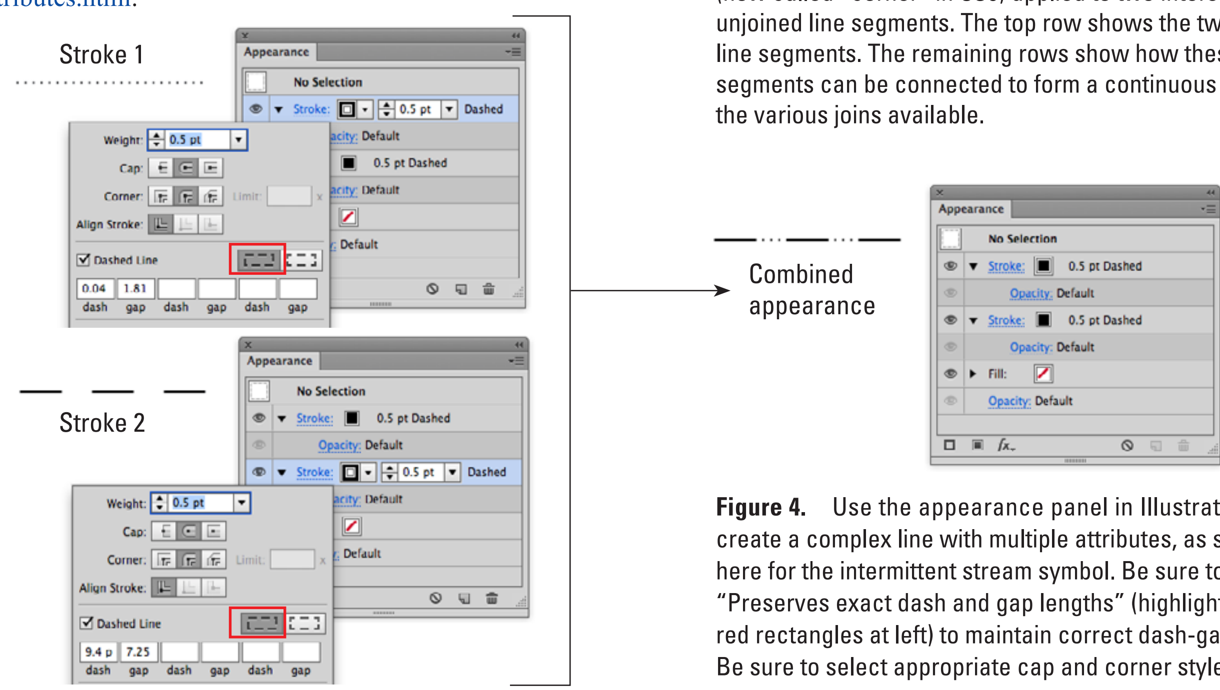


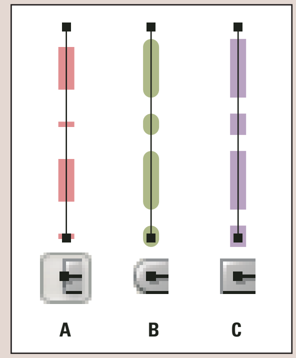
Figure 4. Use the appearance panel in Illustrator to create a complex line with multiple attributes, as shown here for the intermittent stream symbol. Be sure to select "Preserves exact dash and gap lengths" (highlighted by red rectangles at left) to maintain correct dash-gap length. Be sure to select appropriate cap and corner styles.

Creating Dotted or Dashed Lines Using Caps and Joins

Create dotted or dashed lines

You can create a dotted or dashed line by editing an object's stroke attributes.

1. Select the object.
2. In the Stroke panel, select Dashed Line. If the Dashed Line option is not showing, choose Show Options from the Stroke panel menu.
3. Specify a dash sequence by entering the lengths of dashes and the gaps between them. The numbers entered are repeated in sequence so that once you have established the pattern, you do not need to fill in all the text boxes.
4. Select a cap option to change the ends of the dashes. The Butt Cap option creates square-ended dashes; the Round Cap option creates rounded dashes or dots; the Projecting Cap option extends the ends of dashes.



6-point dashed lines with dash gaps of 2, 12, 16, 12. A, Butt cap. B, Round cap. C, Projecting cap.

Modified from "Illustrator Help/Stroke an object" (available at http://helpx.adobe.com/illustrator/using/stroke-object.html); then click on "Create dotted or dashed lines."

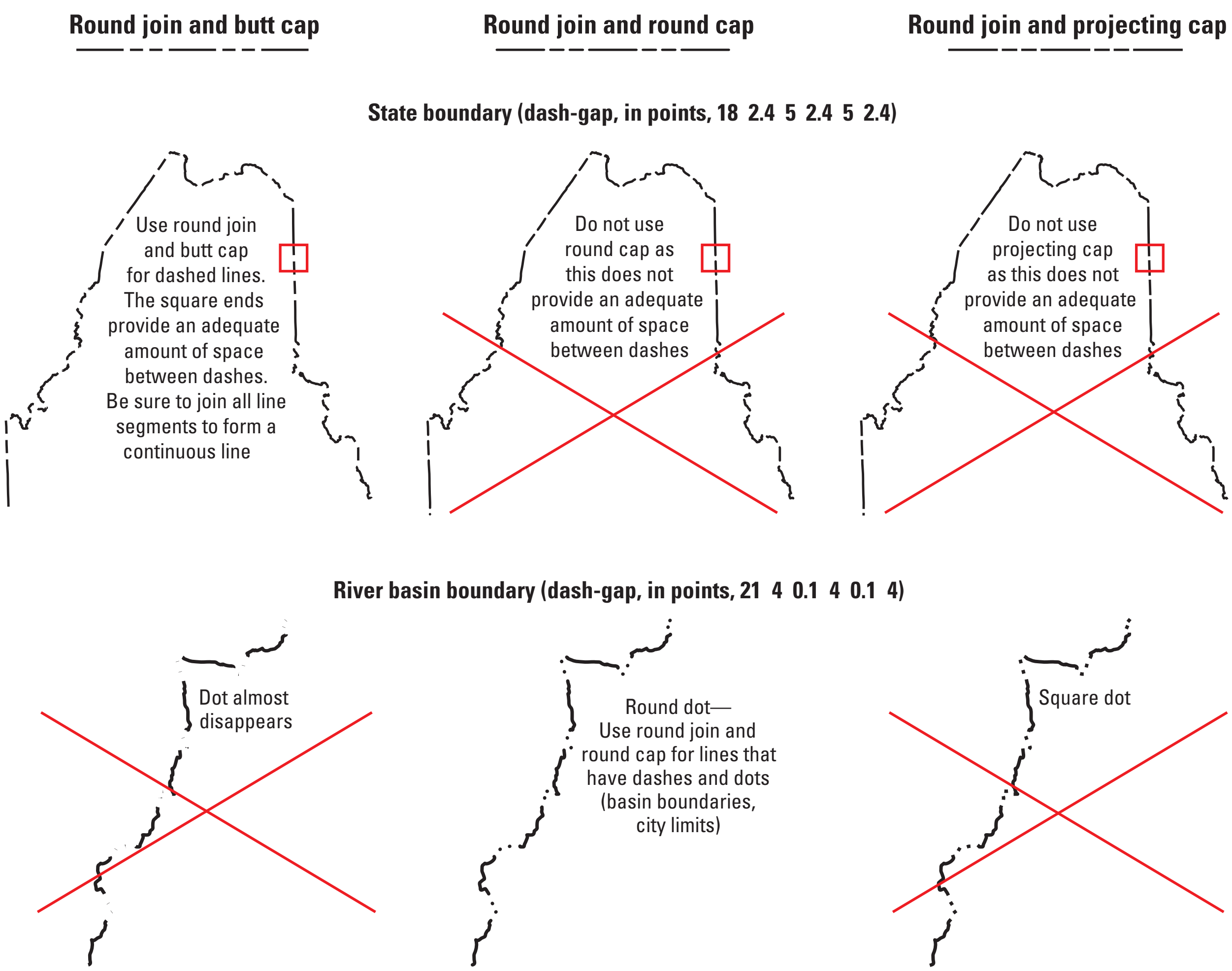


Figure 5. Three alternatives for creating dotted and dashed lines. Using the same dash "recipe" and the various combinations of the caps and joins can give a wide variety of results, some of which are less than ideal.

Colors, Patterns, and Symbols

Introduction

"The goal in color design is to enhance the legibility of the map [or illustration], as well as to lend meaning to the data presented by helping to focus attention on a particular map [or illustration] feature or group of features. Colors and patterns should not, however, be so visually dominant as to distract from the purpose of the map [or illustration]. A well-balanced color design can greatly improve the presentation of scientific information" (U.S. Geological Survey, 2006, p. 24) and is dependent on the good judgment and discretion of the illustrator.

To begin this section on color, a brief description of color theory is given (p. 17). On page 18, the topic of 508 compliancy is discussed. Adobe Illustrator and Photoshop have a viewing option that allows the user to preview colors in an illustration as a person who has either protanopia or deuteranopia would see the colors. The steps to activate this feature are described. A method to test a figure for 508 compliancy also is included.

On geologic maps, color is primarily determined by age and type of rock (see pages 19–20 for color palettes). On hydrologic maps, data "are frequently shown in two or three colors. On maps showing depth to water table, color ranges from light blue at the shallowest depths to dark blue at the greatest depths. On maps showing dissolved-solids concentrations, color ranges from dark blue where concentration is lowest to dark red where concentration is highest" (U.S. Geological Survey, 2006, p. 25).

If the illustration being designed does not have preordained colors, ColorBrewer (available at http://colorbrewer2.org) is a fun Web site to explore. ColorBrewer can provide suggestions of color ramps or schemes that are "colorblind [sic] safe," "photocopy-able," or "print friendly."

In general, small areas should be shown in darker (or greater contrast) colors, and large areas should be shown in lighter (or less contrast) colors. The minimum size of an area that can show color is about 2 square millimeters; anything smaller will need to be labeled.

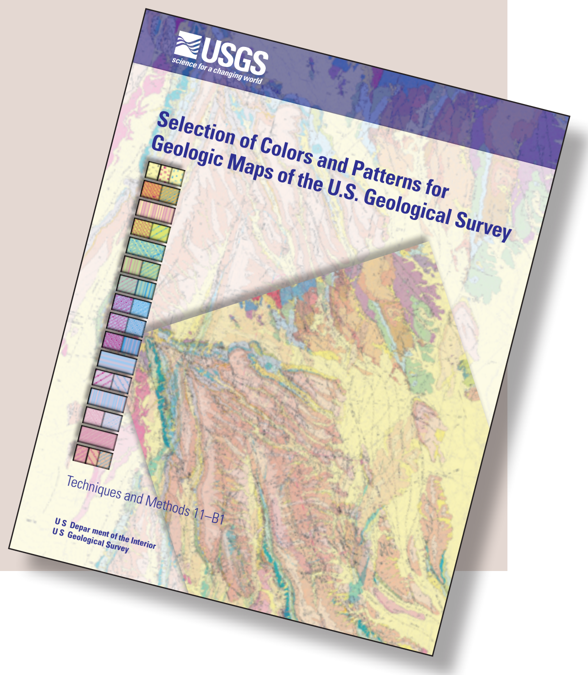
Patterns can be printed either in black, in color, or as a dropout. Ideally, patterns should be used sparingly, and only when necessary for clarification, as they can add unnecessary complexity to an illustration. "In addition, exercise caution when using patterns in small areas because small areas may fail to show enough of the pattern to adequately identify a map unit; about 1 square centimeter is the minimum size to clearly show patterns" (U.S. Geological Survey, 2006, p. 25). Label and leader, as needed. Figures 10 and 11 (p. 22–23) show a sampling of lithologic patterns available for use in page-size illustrations. The complete set of lithologic patterns can be downloaded from section 37 of the FGDC Standard (available at http://pubs.usgs.gov/tm/2006/11A02/).

Geologic and hydrologic symbols are used to represent data that have been collected by the scientist and compiled on a base. These symbols may pertain to a planar feature (for example, the orientation (strike and dip) of layers of sediments), a linear feature (for example, the general direction of groundwater flow or the plunge of a fold axis), or a locality (for example, a water-quality monitoring site or a fossil locality). Table 6 shows a set of symbols most commonly used in page-size illustrations. These symbols are but a subset of symbols available for use by the visual information specialist. A more extensive set of symbols can be downloaded from the FGDC Standard (available at http://pubs.usgs.gov/tm/2006/11A02/). The USGS Hydro Font (see section on type specifications and fonts) also can be accessed as a symbol set that can be loaded into Adobe Illustrator.

"A well-balanced color design can greatly improve the presentation of scientific information" and is dependent on the good judgment and discretion of the illustrator.

For a comprehensive discussion on selecting colors, patterns, and symbols for use on geologic maps, please consult the following publications:

USGS Techniques and Methods 11–A2, FGDC Digital Cartographic Standard for Geologic Map Symbolization (available at http://pubs.usgs.gov/tm/2006/11A02/)



USGS Techniques and Methods 11–B1, Selection of Colors and Patterns for Geologic Maps of the U.S. Geological Survey (available at http://pubs.usgs.gov/tm/2005/11B01/)

Use of Color

Color Theory

Primary colors are sets of colors that can be combined to create a useful range of color. Additive primary colors—red, green, and blue (RGB)—are the hues used to create color with reflected light, such as the colors seen on a television screen or computer monitor. When these three colors are added together, white is produced (fig. 6*A*).

Subtractive primary colors—cyan, magenta, and yellow (CMY)—are the hues used to create color with pigment or ink, such as the colors seen on a printed page. When these three colors are added together, black is produced (fig. 6*B*).

The human eye perceives a wide range of color; a computer monitor displays a smaller subset of color; and a printer (offset, laser, wax, and so forth) prints an even smaller subset of color (fig. 6*C*). Brightest colors are lost as the color space decreases; really bright reds, greens, and blues that can be displayed on a monitor *cannot* be reproduced on a printer. This explains why illustrations that are created using RGB may look completely different when printed (using your monitor, compare the greens in figure 6*A* and *B*) and also why all illustrations should be created using CMYK. If the illustration is to be served on the Web, it can then be converted to RGB, which results in a smaller file size.

In these standards, colors are suggested, for the most part, in CMYK. In a few instances, however, suggested colors for certain symbols and lines are given as 100 percent red (dikes, for example), 100 percent green (water-quality-zone contours, for example), or 100 percent violet (bedrock contours, for example), on the basis of what is stated in the FGDC Standard. In these standards, these three colors have been converted to CMYK.

Table 5. Colors and connotations.

[Modified from Littlefield and Kirkpatrick, 1970; Hackl, 1980; Marshall Editions Limited, 1980]

Color	Connotation
Red	Action, life, blood, fire, heat, passion, danger, power, loyalty, bravery, anger, excitement; strong red—warning
Orange	Harvest, fall, middle life, tastiness, abundance, fire, attention, action; strong orange—warning
Yellow	Cheerfulness, dishonesty, youth, light, hate, cowardice, joyousness, optimism, spring, brightness; strong yellow—warning
Green	Immaturity, youth, spring, nature, envy, greed, jealousy, cheapness, ignorance, peace; medium green—subdued
Blue	Coldness, serenity, depression, melancholy, truth, purity, formality, depth, restraint; dark blue—silence, loneliness
Purple (violet)	Dignity, royalty, sorrow, despair, richness; maroon—elegant, painful
Earth colors (reddish brown, russet, and ochre)	Warmth, cheer, deep worth, and elemental root qualities; can be friendly, cozy, dull, reassuring, or depressing
White	Cleanliness, faithfulness, purity, sickness
Gray	Quiet and reserved, controlled emotions; can be used to create sophisticated atmosphere
Black	Mystery, strength, mourning, heaviness

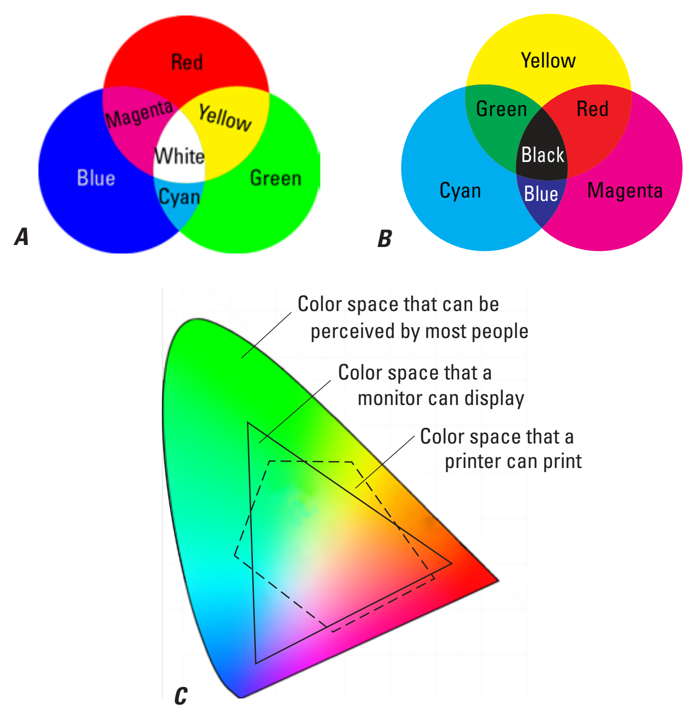


Figure 6. Additive and subtractive primary colors and a modified chromaticity diagram. *A*, When two additive primary colors overlap, a subtractive primary color is produced. When all three additive primary colors are combined, white is produced. *B*, When two subtractive primary colors overlap, an additive primary color is produced. When all three subtractive primary colors are combined, black is produced. *C*, A modified chromaticity diagram, originally developed by the Commission Internationale d'Eclairage in 1931, comparing color spaces. Note: The possibility of recreating the number of colors that can be perceived by most people diminishes for monitors and printers.

508 Compliancy

The 1998 amendment to Section 508 of the Rehabilitation Act requires that a person with a disability who is seeking information or services from a Federal agency has access to and use of the same information and data as a person without a disability, unless an undue burden would be imposed on that Federal agency.

At the USGS, maps have been given "undue burden" status because of their complexity. However, every effort must be made to make all page-size illustrations 508 compliant. To make an illustration 508 compliant means to create a graphic that when printed in black and white has sufficient contrast within the elements of data to allow a person with a color-blind disability to easily comprehend the information presented in the graphic.

When an illustration containing many color elements (fig. 7*A*, *C*) is converted to grayscale (fig. 7*B*, *D*), it can be difficult to distinguish one line from another or one area from another because of the subtle differences in gray tone. Although color is one means of communicating scientific information, symbology and (or) labeling are also important.

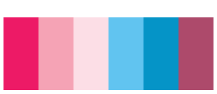
When designing illustrations for 508 compliancy, it is important to note that one common attribute to all types of color-blind disability (except monochromatic) is the inability to distinguish between red and green; therefore it is suggested that using these two colors together be avoided.

Adobe Illustrator and Photoshop have created a helpful feature that allows the user to view files through the eyes of someone who has either protanopia or deuteranopia. To activate this feature, go to the main menu bar and select "View," then "Proof Setup," then either "Protanopia-type" or "Deuteranopia-type." Return to original colors by selecting "Proof Setup."

People who have **trichromacy** (normal color vision) see the full spectrum of rainbow colors.

People who have **deuteranopia** exhibit a weakness perceiving green, so that red, orange, and green appear brownish, and blue and purple look very similar. Occurs in 5 to 8 percent of the male population.

People who have **protanopia** exhibit a weakness perceiving red, so that red appears brownish, orange and green appear beige or gold, and blue and purple look very similar. Occurs in 1 percent of the male population.



People who have **tritanopia** exhibit a weakness perceiving blue, so that blue and green look very similar, and yellow, orange, and red appear as light to dark shades of pure magenta. Occurrence is very rare.

People who have **monochromacy** (total color blindness) can see only in black and white. Occurrence is extremely rare.

Color bars from Kiff (2011).

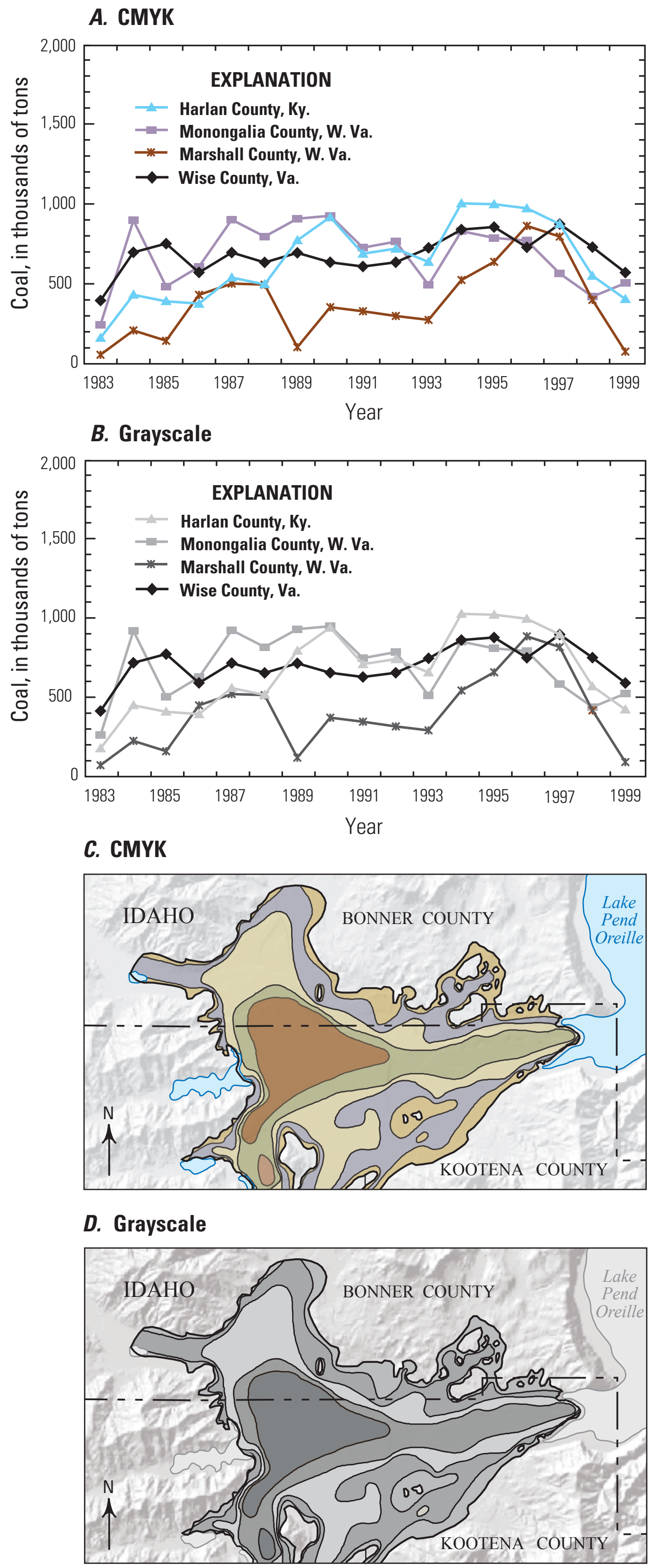


Figure 7. One method to test for 508 compliancy. To see if colors chosen for a figure can be easily distinguished by a person with a color-blind disability, print the figure in black and white. Compare *A* with *B* and *C* with *D*.

Geologic Map-Unit Colors

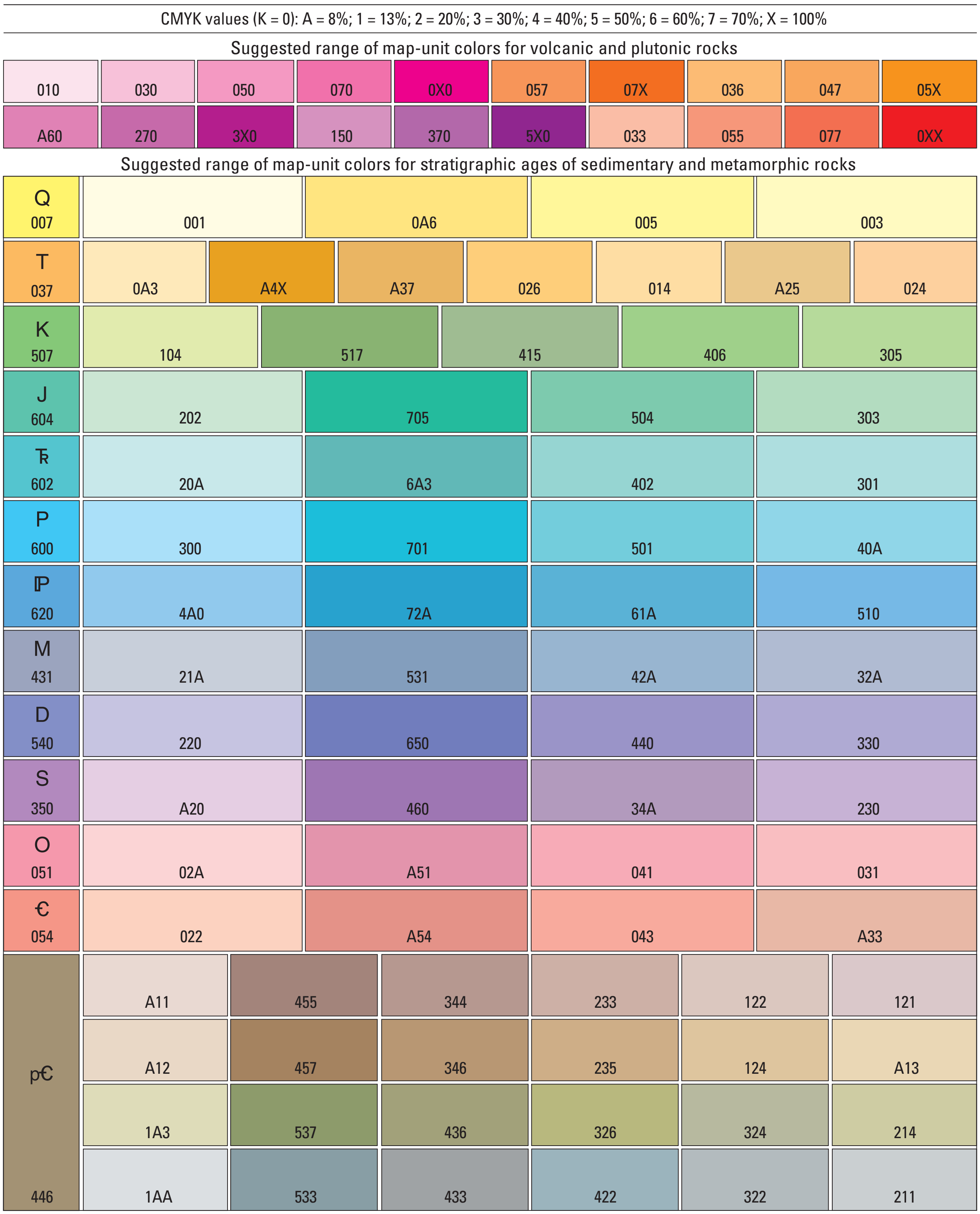


Figure 8. Suggested ranges of map-unit colors for volcanic and plutonic rocks and for stratigraphic ages of sedimentary and metamorphic rocks for large-scale and regional geologic maps of the United States. This palette and a custom-color palette can be downloaded from section 33 of the "FGDC Digital Cartographic Standard for Geologic Map Symbolization" (available at http://pubs.usgs.gov/tm/2006/11A02/). For international maps or small-scale maps (for instance, 1:5 million) of the United States or North America, use the international colors (available at http://stratigraphy.science.purdue.edu/charts/rgb.html; click on "Charts & Books"; then click on "Color Codes"). Age symbols are defined in table 2. C, cyan; M, magenta; Y, yellow; K, black.

Divisions of Geologic Time—Major Chronostratigraphic and Geochronologic Units

Introduction

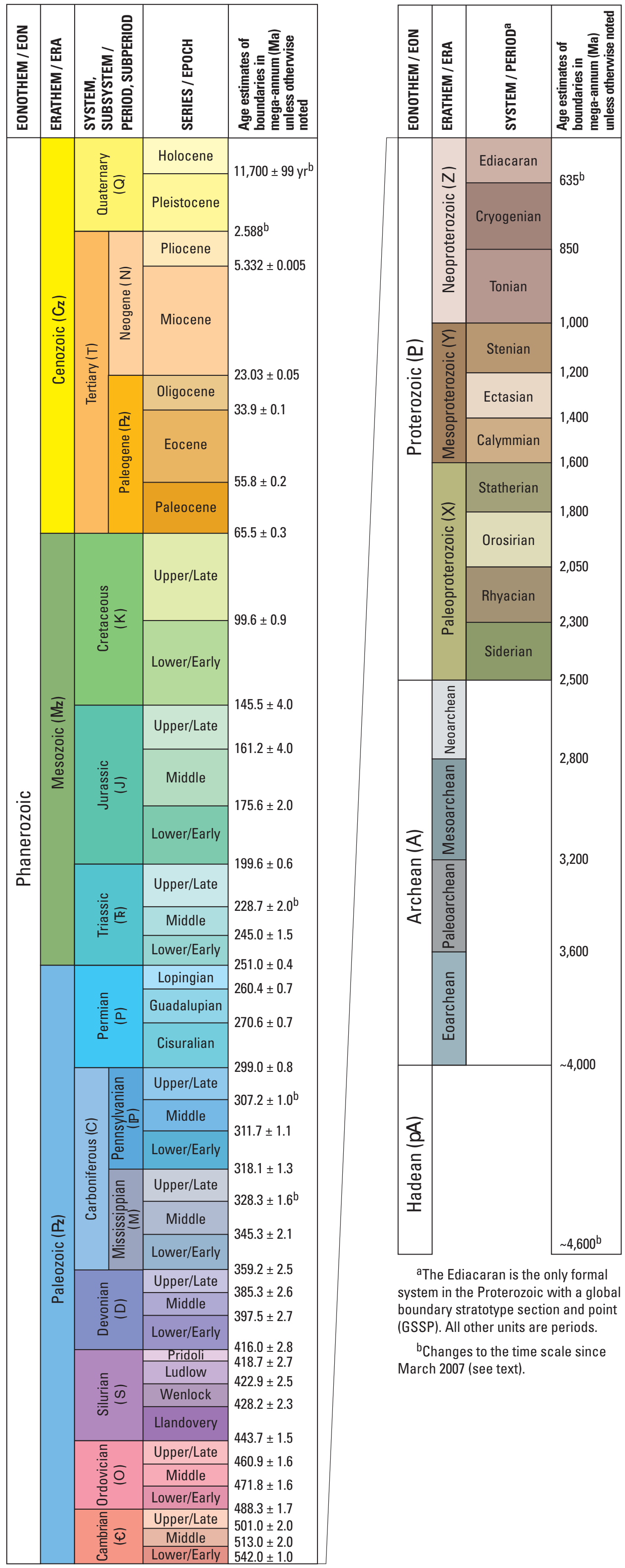
Effective communication in the geosciences requires consistent uses of stratigraphic nomenclature, especially divisions of geologic time. A geologic time scale is composed of standard stratigraphic divisions based on rock sequences and is calibrated in years (Harland and others, 1982). Over the years, the development of new dating methods and the refinement of previous methods have stimulated revisions to geologic time scales.

Since the mid-1990s, geologists from the USGS, State geological surveys, academia, and other organizations have sought to create a consistent time scale to be used in communicating ages of geologic units in the United States. Many international debates have occurred over names and boundaries of units, and various time scales have been used by the geoscience community.

New Time Scale

Since publication of a chart showing divisions of geologic time in the seventh edition of the USGS guide *Suggestions to Authors* (Hansen, 1991), no other time scale has been officially endorsed by the USGS. For consistent usage of time terms, the USGS Geologic Names Committee (GNC) and the Association of American State Geologists developed "Divisions of Geologic Time" (fig. 9), which represents an update containing the unit names and boundary age estimates ratified by the International Commission on Stratigraphy (ICS). Scientists should note that other published time scales may be used, provided that these are specified and referenced (for example, Palmer, 1983; Harland and others, 1990; Haq and Eysinga, 1998; Gradstein and others, 2004; Ogg and others, 2008).

Advances in stratigraphy and geochronology require that any time scale be periodically updated. Therefore, Divisions of Geologic Time (fig. 9) is intended to be a dynamic resource that will be modified to include accepted changes of unit names and boundary age estimates.



[a]The Ediacaran is the only formal system in the Proterozoic with a global boundary stratotype section and point (GSSP). All other units are periods.

[b]Changes to the time scale since March 2007 (see text).

Figure 9. Divisions of geologic time approved by the U.S. Geological Survey Geologic Names Committee, 2010. The chart shows major chronostratigraphic and geochronologic units. It reflects ratified unit names and boundary estimates from the International Commission on Stratigraphy (Ogg, 2009). Map symbols are in parentheses.

Divisions of Geologic Time (fig. 9) shows the major chronostratigraphic (position) and geochronologic (time) units; that is, eonothem/eon to series/epoch divisions. Scientists should refer to the ICS time scale (Ogg, 2009) and resources on the National Geologic Map Database Web site (http://ngmdb.usgs.gov/Info/standards/) for stage/age terms. Most systems of the Paleozoic and Mesozoic are subdivided into series using the terms “Lower,” “Middle,” and “Upper.” The geochronologic counterpart terms for subdivisions of periods are “Early,” “Middle,” and “Late.” The international geoscience community is applying names to these subdivisions based on stratigraphic sections at specific localities worldwide. All series/epochs of the Silurian and Permian Systems have been named, and although usage of these names is preferred, “lower/early,” “middle,” and “upper/late” are still acceptable as informal units (lowercase) for these two systems/periods.

In the ICS time scale, the uppermost part of the Cambrian has been named "Furongian," and the lowermost part has been named "Terreneuvian. The GNC, however, will not include these names in the Divisions of Geologic Time until all series/epochs of the Cambrian are named.

Cenozoic

A controversial issue during the first decade of the 21st century was the position of the base of the Quaternary System/Period and its status as a formal division of time. After much debate, the International Union of Geological Sciences formally ratified a new definition of the base of the Quaternary and the corresponding base of the Pleistocene Series/Epoch, changing its age from 1.806 Ma to 2.588 Ma (see box for age terms) (Gibbard and others, 2010). This is a major change from the 2007 time scale (U.S. Geological Survey Geologic Names Committee, 2007) and the one published in Hansen (1991). Although the Tertiary is not recognized by many international time scales, the GNC agrees that it is important that it be recognized as a system/period; the map symbols “T” (Tertiary) and “Q” (Quaternary) have been used on geologic maps for more than a century and are widely used today.

Another change to the time scale is the age of the base of the Holocene Series/Epoch. The boundary is now defined on the basis of an abrupt climate change recorded by indicators in a Greenland ice core (Walker and others, 2009). The Pleistocene-Holocene boundary is dated at 11,700 calendar years before A.D. 2000.

Age Terms

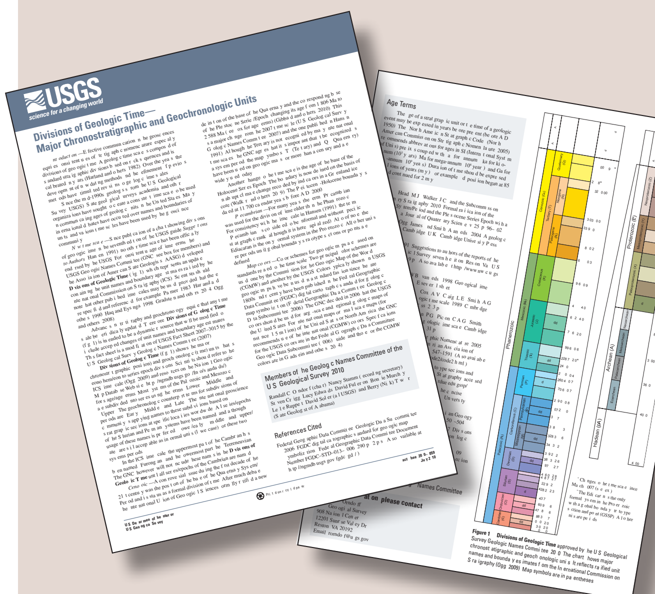
The age of a stratigraphic unit or the time of a geologic event may be expressed in years before present (before A.D. 1950). The “North American Stratigraphic Code” (North American Commission on Stratigraphic Nomenclature, 2005) recommends abbreviations for ages in SI (International System of Units) prefixes coupled with “a” for “annum”: ka for kilo-annum (10^3 years); Ma for mega-annum (10^6 years); and Ga for giga-annum (10^9 years). Duration of time should be expressed in millions of years (m.y.); for example, “deposition began at 85 Ma and continued for 2 m.y.”

Precambrian

For many years, the term “Precambrian” was used for the division of time older than the Phanerozoic. For consistency with the time scale in Hansen (1991), the term “Precambrian” is considered to be informal and without specific stratigraphic rank (although it is here capitalized). Also of note, the Ediacaran is the only formal system in the Proterozoic. All other units are periods until global boundary stratotype sections or points are defined.

Map Colors

Color schemes for geologic maps are based on standards related to the time scale. Two principal color schemes are used, one by the Commission for the Geologic Map of the World (CGMW) and another by the USGS. Colors typically shown on USGS geologic maps have been used in a standard fashion since the late 1800s and recently have been published in the FGDC Standard (U.S. Geological Survey, 2006). The GNC decided in 2006 that the USGS colors should be used for large-scale and regional geologic maps of the United States. For international maps or small-scale maps (for instance, 1:5 million) of the United States or North America, the GNC recommends use of the international (CGMW) colors. Specifications for the USGS colors are in the FGDC Standard, and those for the CGMW colors are in Gradstein and others (2004).

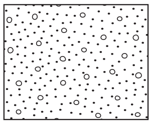


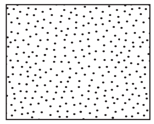
Note: Pages 20 and 21 are modified from **Fact Sheet 2010–3059: Divisions of Geologic Time—Major Chronostratigraphic and Geochronologic Units**, available at http://pubs.usgs.gov/fs/2010/3059/.

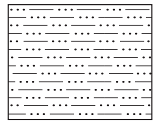
Use of Patterns

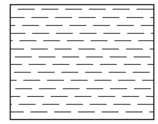
(Lithologic patterns are usually reserved for use on stratigraphic columnar sections or cross sections)

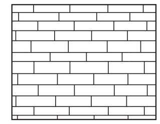
Sedimentary rock

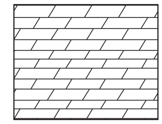

601
Gravel or conglomerate


607
Massive sand or sandstone

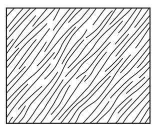

616
Silt, siltstone, or shaly silt

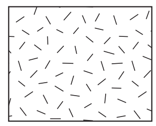

620
Clay or clay shale

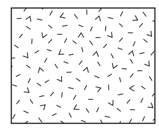

627
Limestone


642
Dolostone or dolomite

Metamorphic and igneous rock


705
Schist


718
Granite


722
Igneous rock

List of patterns shown in CS2.ZIP file from section 37 of the FGDC Standard

FGDCgeostdTM11A2_A-37-01cs2.eps

Breccia
Chalk
Dolostone or dolomite
- Crossbedded dolostone or dolomite
- Dolomitic limestone, limy dolostone, or limy dolomite
- Dolostone or dolomite
- Oolitic dolostone or dolomite

Gravel or conglomerate
- Crossbedded gravel or conglomerate

Limestone
- Argillaceous or shaly limestone
- Cherty and sandy crossbedded clastic limestone
- Cherty crossbedded limestone
- Cherty limestone
- Clastic limestone
- Crossbedded limestone
- Fossiliferous clastic limestone
- With irregular (burrow?) fillings of saccharoidal dolomite
- Nodular or irregularly bedded limestone
- Oolitic limestone
- Sandy limestone
- Silty limestone

Sand or sandstone
- Argillaceous or shaly sandstone
- Bedded sand or sandstone
- Calcareous sandstone
- Crossbedded sand or sandstone
- Dolomitic sandstone
- Massive sand or sandstone
- Ripple-bedded sand or sandstone

Shale
- Calcareous shale or marl
- Carbonaceous shale
- Cherty shale
- Clay or clay shale
- Dolomitic shale
- Oil shale
- Sandy or silty shale

Silt, siltstone, or shaly silt
- Calcareous siltstone
- Dolomitic siltstone

FGDCgeostdTM11A2_A-37-02cs2.eps

Bentonite
Chert
- Bedded chert
- Fossiliferous bedded chert

Coal
- Bony coal or impure coal

Dolomite or dolostone
- Argillaceous or shaly dolostone or dolomite
- Cherty dolostone or dolomite
- Sandy dolostone or dolomite
- Silty dolostone or dolomite

Flint clay
Glauconite
Gypsum
Interbedded rock
- Calcareous shale and limestone (shale dominant)
- Limestone and calcareous shale
- Limestone and shale
- Limestone and shale (limestone dominant)
- Ripple-bedded sandstone and shale
- Sandstone and shale
- Sandstone and siltstone
- Shale and limestone (shale dominant)
- Shale and silty limestone (shale dominant)
- Silty limestone and shale

Limonite
Loess
Peat
Rock
- Diatomaceous rock
- Fossiliferous rock
- Phosphatic-nodular rock

Salt
Siderite
Subgraywacke
- Crossbedded subgraywacke
- Ripple-bedded subgraywacke

Till or diamicton
Underclay

FGDCgeostdTM11A2_A-37-03cs2.eps

Basaltic flows
Breccia
- Volcanic breccia and tuff
- Volcanic breccia or agglomerate

Gneiss
- Contorted gneiss

Granite
- Schistose or gneissoid granite

Igneous rock (many options)
- Banded igneous rock

Metamorphism
Ore
Porphyritic rock
Quartz
Quartzite
Schist
- Contorted schist
- Schist and gneiss

Slate
Soapstone, talc, or serpentinite
Tuff
- Crystal tuff
- Devitrified tuff
- Tuffaceous rock

Vitrophyre
Zeolitic rock

Figure 10. A subset of lithologic patterns that is available for use in page-size illustrations. The complete set of lithologic patterns can be downloaded from section 37 of the "FGDC Digital Cartographic Standard for Geologic Map Symbolization" (available at http://pubs.usgs.gov/tm/2006/11A02/).

Geologic age	Pattern color														
	Pattern	C (X000)	M (0X00)	Pattern	C (5000)	M (0500)	Pattern	C (X000)	M (0X00)	Pattern	C (X000)	M (0X00)	Pattern	K (0005)	
Quaternary Q	101	0000	0030	117	0000	0030	429	0000	0030	402	0000	0030	101	0000	0030
Tertiary T	101	A130	0270	301	A130	0270	318	A130	0270	327	A130	0270	101	A130	0270
Cretaceous K	101	A030	3070	427	A030	3070	301	A030	3070	327	A030	3070	101	A030	3070
Jurassic J	101	3030	6060	118	3030	6060	302	3030	6060	317	3030	6060	301	1020	3030
Triassic TR	101	30A0	6030	416	30A0	6030	327	30A0	6030	314	30A0	6030	317	30A0	4020
Permian P	101	2000	6030	429	2000	6030	328	2000	6030	317	2000	6030	327	1000	3000
Pennsylvanian IP	101	3A00	3200	102	3A00	3200	317	3A00	3200	328	3A00	3200	328	3A00	3200
Mississippian M	101	1100	4300	103	1100	2200	318	1100	4300	327	1100	4300	319	1100	2200
Devonian D	117	32A0	3320	103	2210	32A0	319	32A0	3320	318	32A0	3320	314	2210	32A0
Silurian S	117	1200	1500	401	1200	A300	303	1200	1500	319	1200	1500	101	1200	A300
Ordovician O	117	03A0	06A0	116	03A0	A3A0	305	03A0	06A0	327	03A0	06A0	101	03A0	A3A0
Cambrian €	117	0120	2440	118	0120	02A0	315	0120	2440	318	0120	2440	101	0120	02A0
Precambrian[1] p€	117	2140	1230	302	2140	1230	306	2140	1230	327	2140	1230	416	2140	1230

[1]Includes Proterozoic and Archean.

Figure 11. Selected examples of ***background colors*** (CMYK codes shown below color boxes) and various **point patterns** (pattern numbers shown above color boxes) for geologic maps. CMYK values: A = 8%; 1 = 13%; 2 = 20%; 3 = 30%; 4 = 40%; 5 = 50%; 6 = 60%; 7 = 70%; X = 100%. Figure modified from U.S. Geological Survey (2005). C, cyan; M, magenta; Y, yellow; K, black.

Use of Symbols

Table 6. Geologic and hydrologic symbols commonly used in page-size illustrations and corresponding keystrokes for the FGDCGeoAge and USGS Hydro Fonts.

[Based on Federal Geographic Data Committee (FGDC) standards for a 1:24,000-scale map from “FGDC Digital Cartographic Standard for Geologic Map Symbolization” (available at http://pubs.usgs.gov/tm/2006/11A02/). Modified by the U.S. Geological Survey Illustrations Standards Team, October 2015. Page numbers, shown in parentheses, indicate where the symbol is found in the FGDC Standard. Geologic age symbols from the FGDCGeoAge Font can be downloaded from section 32 of the FGDC Standard. The USGS Hydro Font can be downloaded at http://internal.usgs.gov/publishing/toolboxes/graphic.htm]

Description	Symbol
Fault	
Normal fault (p. A–2–2)	
Strike-slip fault (p. A–2–5)	
Thrust fault (p. A–2–7 to A–2–8)	
Fold	
Anticline (p. A–5–1 to A–5–2)	
Syncline (p. A–5–6 to A–5–7)	
Overturned anticline (p. A–5–3 to A–5–4)	
Overturned syncline (p. A–5–8 to A–5–9)	
Monocline (p. A–5–11 to A–5–12)	
Strike and dip of bedding (p. A–6–1 to A–6–2)	
Inclined	*10*
Vertical	
Horizontal	
Overturned	*75*
Strike and dip of foliation (p. A–8–1 to A–8–5)	
Inclined	*35* *or* *10*
Vertical	*or*
Bearing and plunge of lineation (p. A–9–1 to A–9–6)	
Inclined	*20* *or* *30*
Vertical	*or*
Horizontal	*or*
Quarry (p. A–19–3)	
Active	
Abandoned	
Miscellaneous—Geologic	
Collapse structure or sinkhole (too small to draw to scale) (p. A–23–1)	
Collapse structure or sinkhole (drawn to scale) (p. A–23–1)	
Fossil locality—Showing collection number (p. A–10–1)	D4426
Unconformity	

Description	Symbol
Miscellaneous—General	
City, town	■
Historic site	
Interstate route marker (p. A–28–1)	70
U.S. route marker (p. A–28–1)	10
State route marker (p. A–28–1)	14
North arrow	N
Pi[1]	Π
Railroad	
Registered mark[2]	®

Stratigraphic age	Symbol	Keystrokes for FGDCGeoAge Font[3]
Cenozoic	Cz	{ (left curly bracket = shift–left square bracket).
Paleogene	Pe	: (colon = shift–semi-colon).
Mesozoic	Mz	} (right curly bracket = shift–right square bracket).
Triassic	TR	^ (caret = shift–6).
Paleozoic	Pz	| (vertical line = shift–backslash).
Pennsylvanian	IP	* (asterisk = shift–8).
Cambrian	Є	_ (underscore = shift–hyphen).
Precambrian	pЄ	= (equal sign).
Proterozoic	P	< (“less than” sign = shift–comma).
Neoproterozoic	Z	No keyboard substitution needed.
Mesoproterozoic	Y	No keyboard substitution needed.
Paleoproterozoic	X	No keyboard substitution needed.
Archean	A	No keyboard substitution needed.
Hadean	pA	> (“greater than” sign = shift–period).

Table 6. Geologic and hydrologic symbols commonly used in page-size illustrations and corresponding keystrokes for the FGDCGeoAge and USGS Hydro Fonts.—Continued

[Based on Federal Geographic Data Committee (FGDC) standards for a 1:24,000-scale map from "FGDC Digital Cartographic Standard for Geologic Map Symbolization" (available at http://pubs.usgs.gov/tm/2006/11A02/). Modified by the U.S. Geological Survey Illustrations Standards Team, October 2015. Page numbers, shown in parentheses, indicate where the symbol is found in the FGDC Standard. Geologic age symbols from the FGDCGeoAge Font can be downloaded from section 32 of the FGDC Standard. The USGS Hydro Font can be downloaded at http://internal.usgs.gov/publishing/toolboxes/graphic.htm]

Description	Symbol	Keystrokes for USGS Hydro Font
Water well (p. A–26–1 to A– 26–3)		
Type unspecified	○	Shift 1
Used for domestic-water supply	●	Shift 3
Used for stock-water supply	○	Shift 4
Used for irrigation-water supply	◎	Shift 5
Used for industrial-water supply	◉	Shift 7
Unused		Shift 0
Flowing artesian[4]		Shift 8
Nonflowing artesian[4]		Shift =
Recharge or waste-injection well[4]		-
Observation[4]		.
Observation, equipped with a recorder[4]		/
Abandoned[4]		0
Destroyed[4]		1
Test hole[4]		2
Capped[4]		3
Shut-in[4]		4
Dry hole—Water exploration[4]		5
Used for collection of water data[4]		6
Spring—Tail points in direction of flow (p. A–26–4)		
Type of use unspecified		7
Used for domestic-water supply		8
Used for stock-water supply		9
Used for irrigation-water supply		Shift ;
Used for industrial-water supply		;
Used for collection of water-quality data		Shift ,
Unused		Shift .
Thermal[5]		Shift /
Mineral[5]		Shift 2
Extinct[5]		Shift a
Streamgaging station (p. A–26–5)[6]		
Type of measurement unspecified	△	Shift b
Continuous record	▲	Shift c
Partial record		Shift d
Measurement station without a gage	△	Shift e
Discontinued		Shift f
Equipped with a telephone or radio[7]		Shift g
Peak-flow measurement station[7]		Shift h
Low-flow measurement station[7]		Shift i
Stage-measurement station[7]		Shift j
Continuous-record stage-measurement station		Shift m

Description	Symbol	Keystrokes for USGS Hydro Font
Surface-water-quality monitoring site (p. A–26–6)[8]		
Type of measurement unspecified	▽	Shift n
Active	▼	Shift o
Active, equipped with a monitor	▽	Shift p
Inactive		Shift q
Chemical measurement[9]		Shift r
Temperature measurement[9]		Shift s
Biological measurement[9]		Shift t
Sediment measurement[9]		Shift u
Hazardous waste site (p. A–20–1) (generally shown in red but may be shown in black)		
Type unspecified	▽	Shift n
Showing direction of surface-leachate flow from site		Shift w
Active (operating)	▼	Shift o
Inactive (closed)		Shift q
Clean-up activities are in progress		Shift v
Weather station (p. A–27–1)		
Type of measurement unspecified		a
Complete	◆	d
Equipped with a recorder[10]		b
Equipped with a telephone or radio[10]		c
Precipitation measurement		f
Evaporation measurement		g
Temperature measurement		h
Humidity measurement		i
Solar radiation measurement		j
Wind velocity measurement		k
Discontinued		l
Miscellaneous—Hydrologic (p. A–26–9)		
General direction of groundwater flow (accurately located)	➡ *or* ⇨	m *or* n
General direction of groundwater flow (approximately located)	→ *or* --→	o *or* p

[1]Always use Times New Roman
[2]Symbol must be superscript
[3]See table 2 for more extensive keystroke chart
[4]Symbol may be used with any of the water well symbols shown above
[5]Symbol may be used with any of the spring symbols shown above
[6]Referred to as water gaging station in the FGDC Standard
[7]Symbol may be used with any of the streamgaging station symbols shown above
[8]Referred to as quality-of-water site in the FGDC Standard
[9]Symbol may be used with either of the active water-quality monitoring site symbols shown above
[10]Symbol may be used with either of the weather station symbols shown above

Explanations

Introduction

The USGS uses the term “explanation” (not “legend” or “key”—Johnny Appleseed is a legend, and a key opens a lock) for that part of a figure that includes the information needed to understand what is shown in the figure. All figures should be able to stand alone without reference to the text or to another figure and this is why a well-crafted and complete explanation is an integral part of a figure.

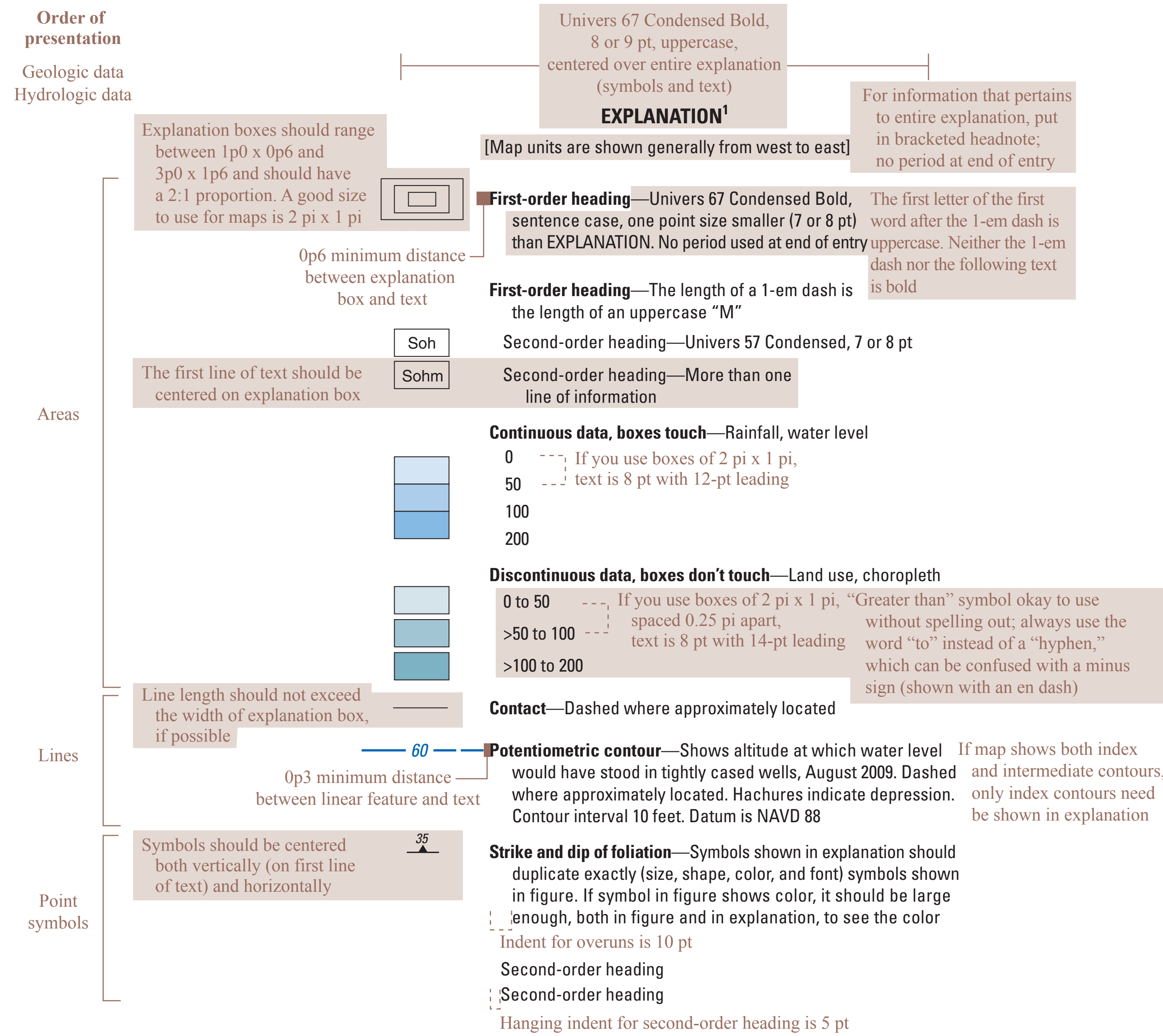
The placement of an explanation—inside or outside the neatline of a figure; to the left of, to the right of, or centered below a figure—depends on the layout of the page. Optimal positioning of the explanation is dependent on the good judgment and discretion of the illustrator and layout person. Placement of the explanation should not obscure data in the figure. The spatial relation between the figure and its explanation should be obvious. Explanations should be sized to best fit the figure and do not necessarily need to be confined in width to one or two columns.

An example of a generic explanation is shown on the next page, which when followed will ensure a consistent look for explanations that are found in USGS information products. See page 29 for the wording to be used in explanations for types of contours and lines of equal. Pages 30 and 31 illustrate—using examples—the differences between continuous and discontinuous (or discrete) data. A number of explanations, which have been published previously in USGS formal-series publications, have been assembled on succeeding pages. The explanations have been modified according to the specifications laid out in the generic explanation. Please note that only VIS-compliant fonts may be used in explanations.

As a rule of thumb, the distance between the term “Explanation” and the first line of text in the explanation should be equal to the height of the word “Explanation.” Always use the term “Explanation” as the heading, even when the explanation is inside a graph.

As a rule of thumb, the distance between the term “Explanation” and the first line of text in the explanation should be equal to the height of the word “Explanation.” Always use the term “Explanation” as the heading, even when the explanation is inside a graph.

General Information for Explanations



[1]For a map figure, the base map provides a reader with context for that map.

Base maps contain reference information that may provide different geospatial information based on what the author is trying to communicate.

Base-map features (for example, State boundaries, roads, streams, buildings, north arrow) generally are not shown in the explanation.

Any base-map feature that might not be recognized should be labeled on the map (if only a few occurrences) or added to the figure explanation (if many occurrences).

Figure 12. A generic explanation for use in page-size illustrations. The explanation must contain a sample of all scientific data not labeled in the figure. It is recommended that as much explanatory information as possible be shown in the figure explanation, rather than in the figure caption.

Examples of Contour Explanations

Use only in reference to altitude. Use the following format for structure, bedrock, water-table, potentiometric, and water-quality-zone contours (p. A–26–7 in FGDC Standard). Closed depression contours are depicted by hachures (p. 66 of these standards).

100% red
PMS 485 U:
100% M
90% Y

100 **Structure contour**—Shows altitude of (top or base of, or horizon within) (stratigraphic unit, aquifer, or confining bed). Dashed where approximately located. Contour interval (number) (units). Datum is (datum)

100% violet
PMS 253 U:
50% C
90% M

100 **Bedrock contour**—Shows altitude of bedrock surface. Dashed where approximately located. Contour interval (number) (units). Datum is (datum)

100% C
60% M

100 **Water-table contour**—Shows altitude of water table, (date). Dashed where approximately located. Contour interval (number) (units). Datum is (datum)

To be used only in reference to unconfined (water-table) conditions.

100 **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells, (date). Dashed where approximately located. Hachures indicate depression. Contour interval (number) (units). Datum is (datum)

To be used in reference to either confined (artesian) or unconfined (water-table) conditions. To be used when both confined and unconfined conditions are not differentiated on the same map. The term “potentiometric contour” is preferred. The term “water-level contour” is permitted.

100 **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells, (date). Dashed where approximately located. Hachures indicate depression. Contour interval, in (units), is variable. Datum is (datum)

To be used when more than one contour interval is shown.

100% green
PMS 354 U:
90% C
85% Y

100 **Water-quality-zone contour**—Shows altitude of (top or base of, or horizon within) (type of water-quality zone or types of water in an aquifer), (date). Dashed where approximately located. Contour interval (number) (units). Datum is (datum)

Examples of Line Explanations

Use when no reference is made to altitude. Use the following format for lines of equal, average, mean, median, and so forth (p. A–26–8 in FGDC Standard). Hachures are not used with lines of equal.

100 **Line of equal (average, mean, or median, and so forth) (annual, monthly, daily, and so forth) precipitation, (date[1])**—Dashed where approximately located. Interval (number) (units)

100 **Line of equal depth to (geologic formation, bedrock, aquifer, water, and so forth), (date[1])**—Dashed where approximately located. Interval (number) (units)

100 **Line of equal thickness of (geologic formation, aquifer, confining bed, saturated material, and so forth), (date[1])**—Dashed where approximately located. Interval (number) (units)

100 **Line of equal water temperature, (date[1])**—Dashed where approximately located. Interval (number) °C

100 **Line of equal specific conductance, (date[1])**—Dashed where approximately located. Interval (number) microsiemens per centimeter at 25 °C

100 **Line of equal (dissolved-solids concentration, hardness, or chemical-constituent concentration), (date[1])**—Dashed where approximately located. Interval (number) milligrams per liter

100 **Line of equal water-level (change, rise, or decline), (date[1])**—Dashed where approximately located. Interval (number) (units)

100 **Line of equal runoff, (date[1])**—Dashed where approximately located. Interval (number) (units) or interval (number) (flow unit) per (area unit)

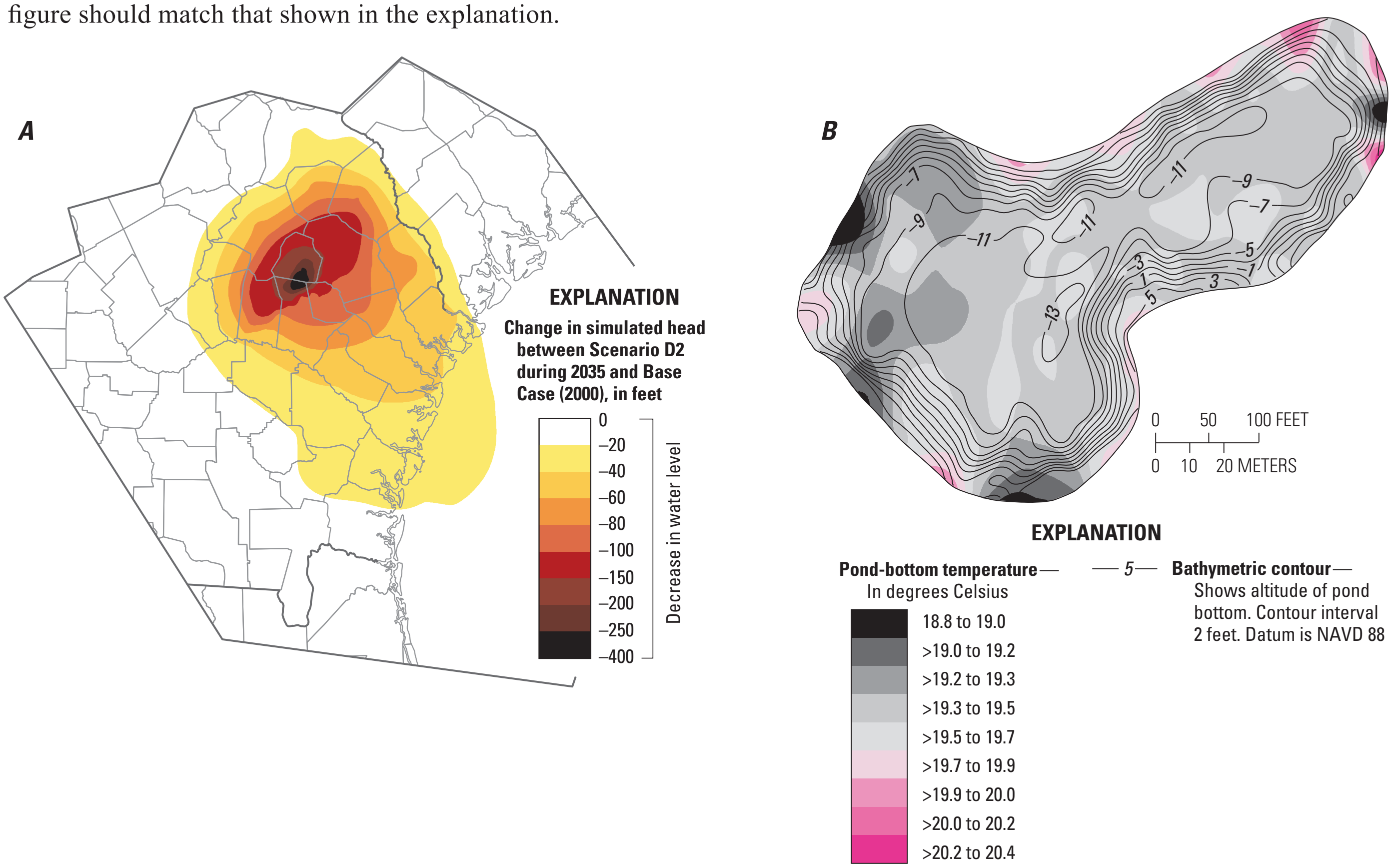
100 **Line of equal (transmissivity, hydraulic conductivity, porosity, and so forth)**—Dashed where approximately located. Interval (number) (units)

[1]Date only for parameters that vary with time; can be omitted from description if given in figure title.

Figure 13. Wording to be used in explanations for geohydrologic contours (where references to an altitude and a datum are made) and geohydrologic lines (when no reference to an altitude is made). PMS, Pantone Matching System®; U, uncoated; C, cyan; M, magenta; Y, yellow; K, black.

Types of Data—Continuous

Continuous data in a figure reflect a range of measurements. The display of colors changes gradationally along a scale extending from one endpoint to another (for example, minimum to maximum). Examples of continuous data include water level, temperature, sediment thickness, elevation, and simulated concentrations. Avoid the use of the "rainbow" color scheme to represent continuous data "because the spectral order of visible light carries no inherent magnitude message. Readers do not automatically perceive violet as greater than red even though the two colors occupy opposite ends of the color spectrum" (Light and Bartlein, 2004, p. 391). For continuous data, color boxes in the explanation should be contiguous. The order of adjoining colors in the figure should match that shown in the explanation.



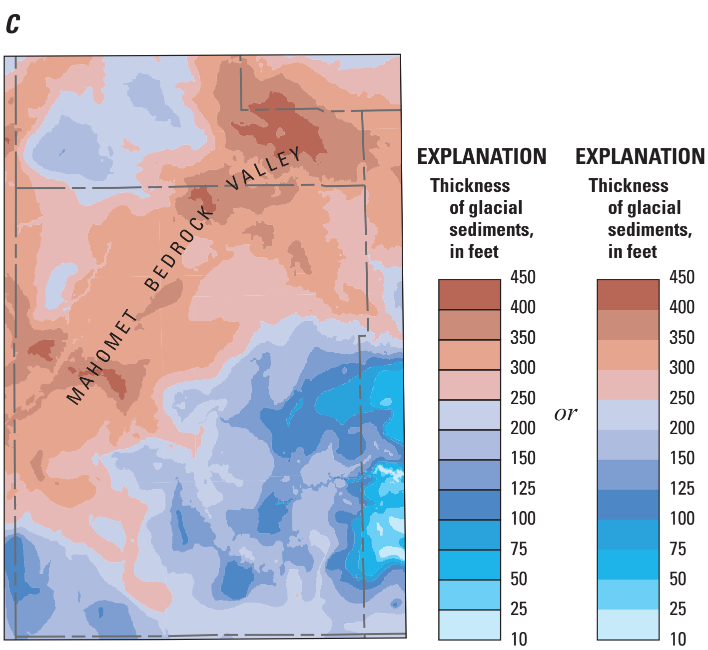
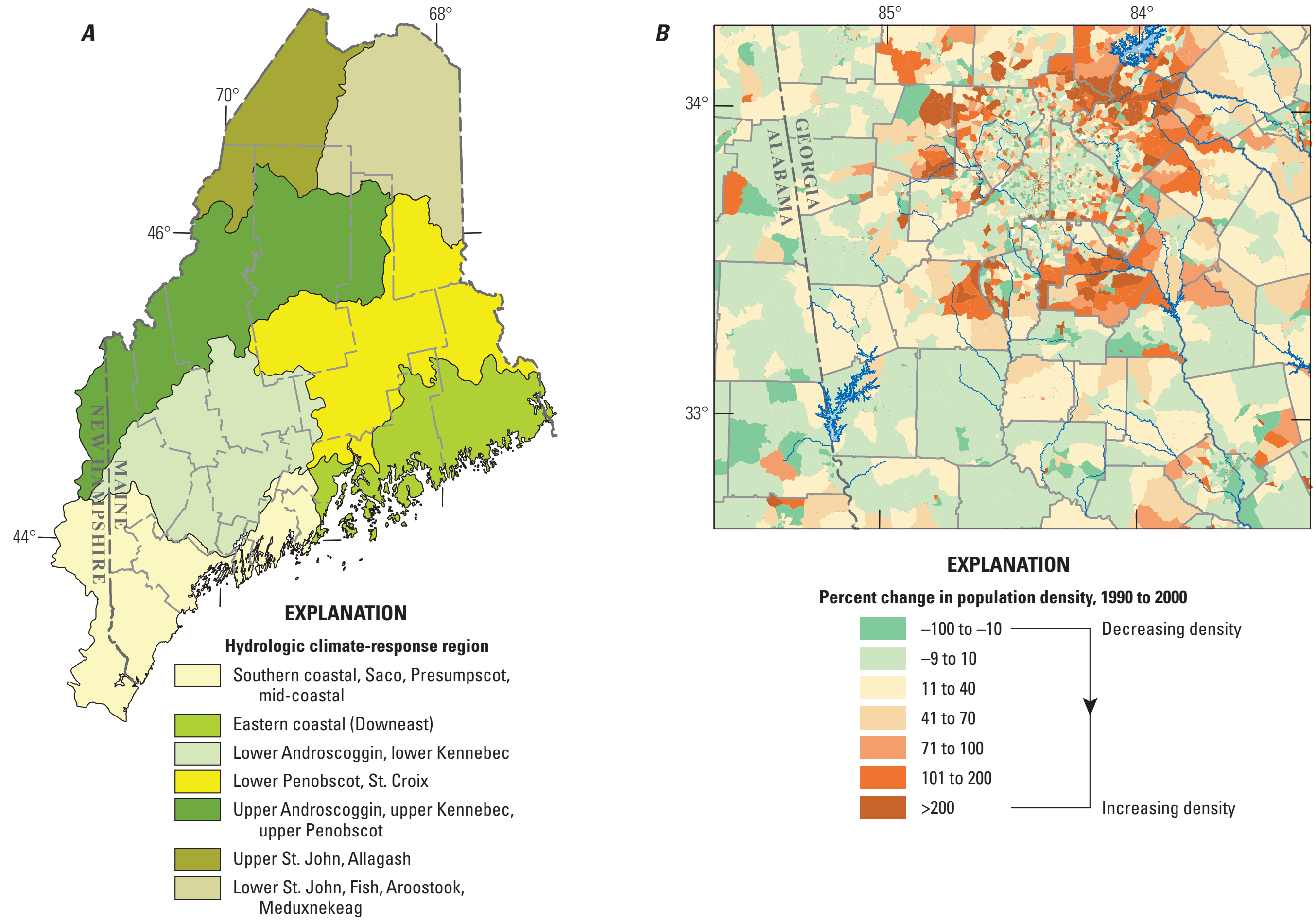


Figure 14. Examples of continuous data; explanation boxes should be contiguous. Two different ways of portraying the relation of color boxes and associated text are shown in the explanations for *A* and *B*. The preferred method is to center the text on the "line" that separates adjacent color boxes because that "line" represents the actual value of the data (*A*). Some authors, however, prefer to show a range of values and center the label on the color box (*B*).

Two different ways of portraying the color boxes are shown in *C*. In the explanation on the left, individual color boxes are outlined in black, even though the colors are not outlined in black in the figure. The editor and cartographer deliberately chose this portrayal in order to assist the reader in differentiating the colors, because this explanation applies to multiple figures on a large map sheet. In the explanation on the right, individual color boxes are not outlined in black, but the entire group of color boxes is outlined in black; this portrayal mirrors what is shown in the figure. *A*, Figure modified from Payne and others (2006). *B*, Figure modified from Clarke and Abu Rumman (2004). *C*, Figure modified from Soller and others (1999).

Types of Data—Discontinuous

Unlike continuous data, discontinuous data (or discrete data) consist of distinct categories of information that can vary in time or space in any order in the figure. Examples of discontinuous data include rock types, choropleth maps (for example, percent change, water withdrawals, and so forth), simulated discharge, and disease occurrence. For discontinuous data, color boxes in the explanation should not be contiguous. The order of adjoining colors in the figure does not necessarily match that shown in the explanation.



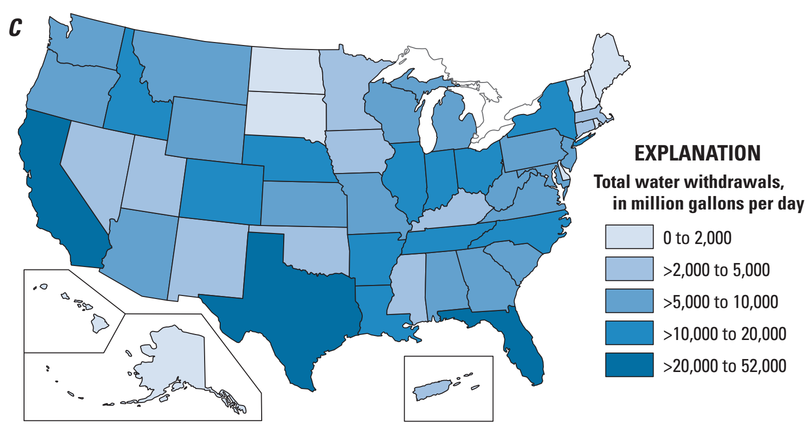
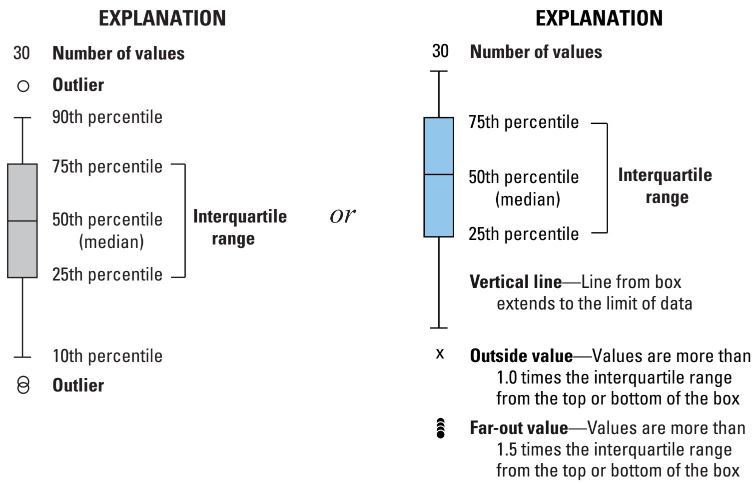


Figure 15. Examples of discontinuous data; explanation boxes should not be contiguous. Ideally, entries shown in the explanation should mirror what is shown in the figure. In the explanations for *A* and *C*, individual color boxes are outlined in black, matching how the colors are displayed in the figures. In the explanation for *B*, individual color boxes are not outlined in black, matching how the colors are displayed in the figure. *A*, Figure modified from Hodgkins and others (2009). *B*, Figure modified from Gregory and Calhoun (2007). *C*, Figure modified from Hutson and others (2004).

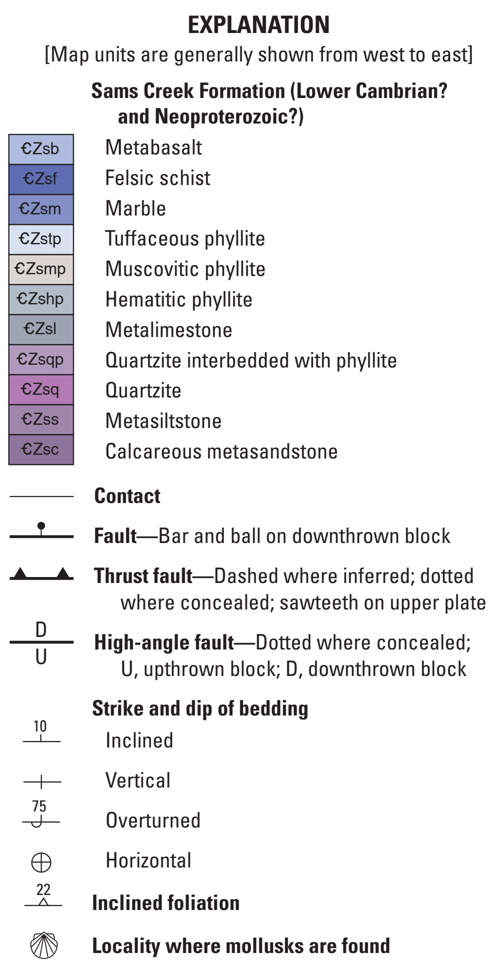
Examples of Explanations

Boxplot



Using color fill for boxplots illustrates the concept of figure-ground. For an explanation of figure-ground organization, see page 128.

Geologic Map



Hydrologic Event

EXPLANATION

Hydrologic and water-related events, October 1988 through September 1989

58 **Flood, localized**—Area affected by excessive runoff or high lake levels

38 **Flood, widespread**—Area affected by excessive runoff

63 **Pollution**—Includes fishkills and toxic spills

22 **Drought**—Unusually dry; deficient streamflow; water shortage. Widespread droughts are listed in table 2 but are not shown on map

81 **Landslide**—Includes mudslides and sinkholes

4 **Unique observation**

Hydrogeologic Map

EXPLANATION

Hydrologic unit

Surficial aquifer system

Upper Floridan aquifer

Upper semiconfining unit

Lower confining unit

Geologic unit

Qu Undifferentiated sediments (Recent and Pleistocene)

Tm Miccosukee Formation (Pliocene)

Th Hawthorn Group (Miocene)

Tsm St. Marks Formation (Miocene)

Ts Suwannee Limestone (Oligocene)

Toc Ocalla Limestone (Eocene)

Tap Avon Park Formation (Eocene)

Hydrogeologic Cross Section

EXPLANATION

Lithologic unit

Sand and clay (Pleistocene)

Silt and clay (Miocene)

Sandstone (Oligocene)

Limestone (Eocene)

Hydrogeologic unit contact

100 **Chloride concentration, in milligrams per liter**—Dashed where inferred

or

EXPLANATION

Sand and clay (Pleistocene)

Silt and clay (Miocene)

Sandstone (Oligocene)

Limestone (Eocene)

Hydrogeologic unit contact

100 **Chloride concentration, in milligrams per liter**—Dashed where inferred

In an explanation, the stratigraphy of an area is presented chronologically with the youngest formation (or aquifer) at the top and the oldest formation (or aquifer) at the bottom.

Graphs and Diagrams

Introduction

Graphs and diagrams, when properly presented, can display numerical information more clearly than tables of numbers, enabling the author to cut back on descriptive text. Care must be taken to choose the proper graph or diagram that will do the best job of showing the data effectively, making clear relations that might not otherwise be understood.

Edward R. Tufte, who was asked to help design the Recovery.gov Web site (www.recovery.gov), contends that the Space Shuttle Challenger never would have exploded in 1986 if the data had been clearly presented using the appropriate type of graph (a scatterplot) with "temperature of field joint" plotted against "o-ring damage" (1997). Oh, the power of a "simple" graph or diagram.

This chapter begins with three pages of general and additional information for graphs and diagrams. Try not to be put off by all the brown type—it might appear, at first glance, to be overwhelming, but bear in mind these pages contain all the information you will need to put together a well-crafted graph or diagram.

This introductory section is followed by two sections, the first titled "Commonly Used Graphs" and the second titled "Commonly Used Diagrams." Eight types of graphs (with some variations) and twelve types of diagrams are shown. A brief description is provided for each graph or diagram, followed by a "general example" and a "specific example." Many of the specific examples have been culled from a variety of USGS information products—geology, minerals, and water.

Many of these graphs and diagrams will be familiar but a few might not be. A bar graph is used to show proportions relative to each other, irrespective of the total. A boxplot is used to summarize large sets of numbers. A pie diagram is used to show proportions of the parts to the whole. A modified piper diagram is used to show the chemical character of a water sample by using plotted points. A stiff diagram is used to show similarities or differences in water composition.

Although these graphs and diagrams vary widely in topic and appearance, all should display the specifications laid out in the first three pages of this section—for example, numbers greater than 999 should have a comma; all axis captions are capped and lowercase (sentence case). All axis captions and labels should be set in Univers 57 Condensed. If space allows, all text in graphs and diagrams should be spelled out. If abbreviations are used, they may be defined in the figure caption.

Edward R. Tufte contends that the Space Shuttle Challenger never would have exploded in 1986 if the data had been clearly presented using the appropriate type of graph. Oh, the power of a "simple" graph or diagram.

General Information for Graphs

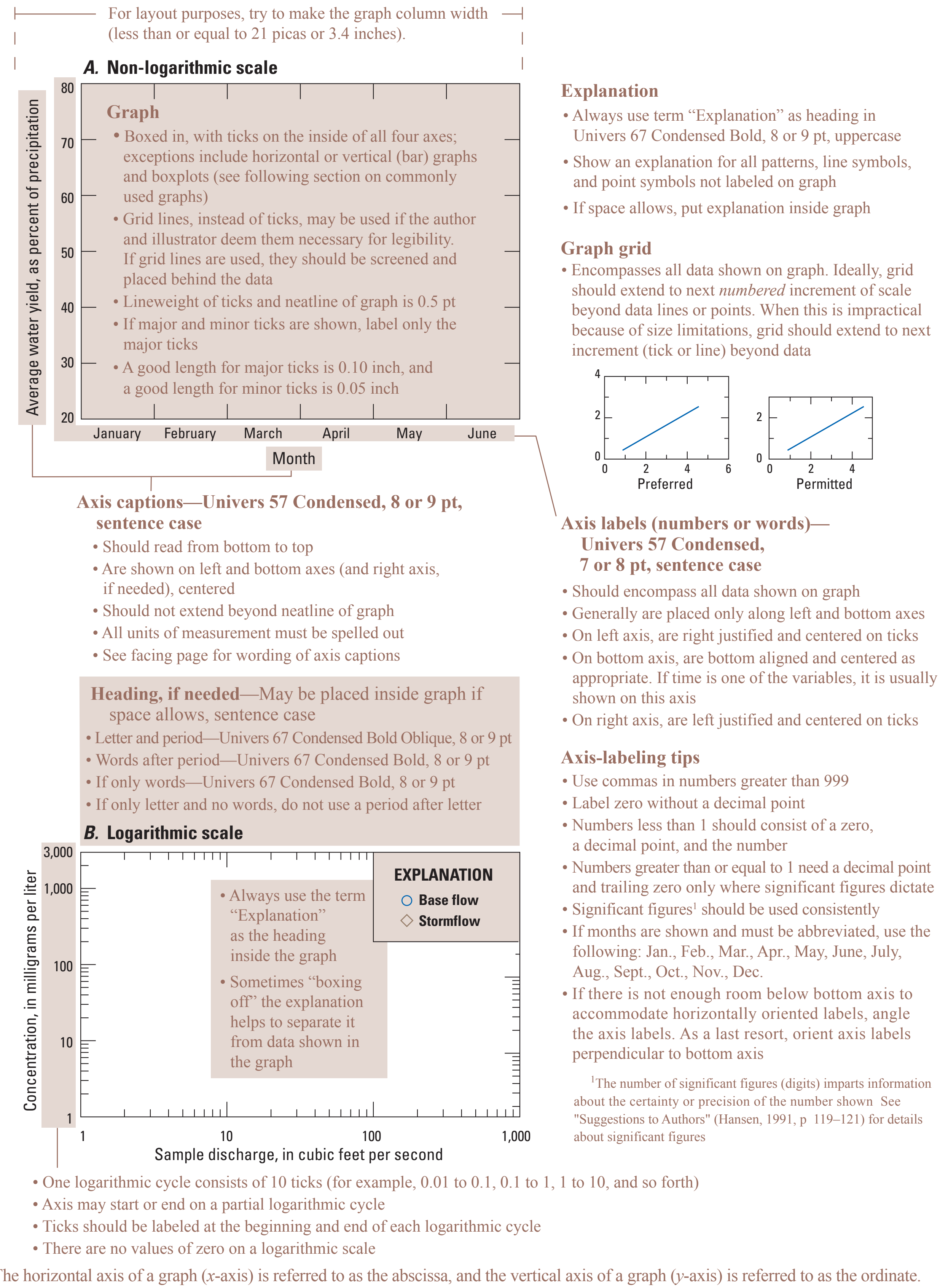
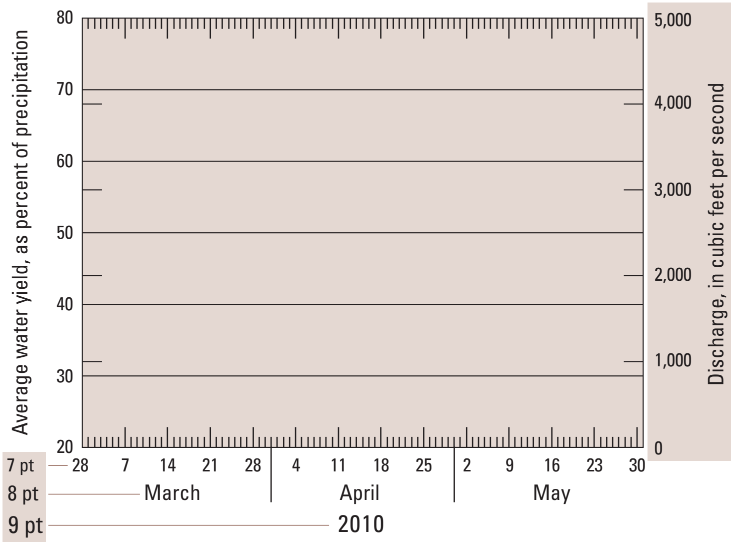


Figure 16 (pages 36 and 37). Generic graphs for use in page-size illustrations.

C. Multivariable, multiscale graph



- If needed for multivariable, multiscale graphs, right axis may be used
- Left axis, rather than right axis, should be used for data of more importance
- Both lines and ticks are used to identify the different scales; the grid for data of more importance (left scale) should consist of lines, and the grid for data of less importance (right scale) should consist of ticks
- The line grid should be drawn completely across the graph, and the ticks should be drawn at the left and right sides of the graph
- All vertical axis captions should read from left to right when the illustration is turned clockwise for viewing

D. Wording of axis captions

- For an axis caption that includes a variable and a unit of measurement, the variable must be followed by a comma, the word “in,” then unit of measurement. For example:
  Discharge, in cubic feet per second
- A unit of measurement can separate or follow the description of a variable. If a unit of measurement separates the description, a comma precedes the unit of measurement but does not follow it. For example:
  Time, in hours after tracer introduced
  Time after tracer introduced, in hours
- The word “percent” is used in axis captions where preceded by the word “in.” The word “percentage” is used where not preceded by the word “in.” For example:
  Dye concentration, in percent of peak concentration
  Percentage of time discharge was equaled or exceeded
- Axis captions should indicate the datum for a variable shown on a graph when a datum exists, such as
  Water level, in feet below land surface
  River stage, in feet above NAVD 88
- For an axis caption that contains an abbreviated letter symbol, the letter symbol should be enclosed in parentheses following the variable and preceding the unit of measurement. For example:
  Oxidation potential (Eh), in millivolts
- The designation of the type of year needs to be added as the axis caption only when the year used is other than a calendar year, such as
  Water year (October 1–September 30)
  Climatic year (April 1–March 31)
- When general relations between parameters are shown without the use of a grid or scale, arrows must be added to show general direction of increasing amount (see scaleless graph on page 41)

Additional Information about Graphs

Data Versus Scale

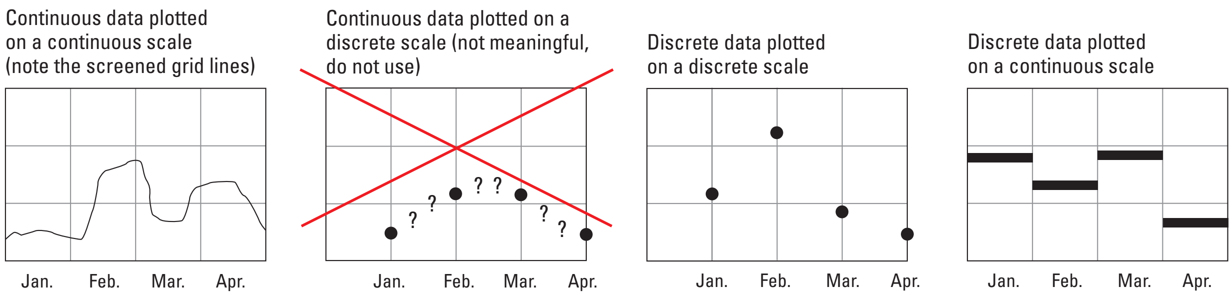


Figure 17. All possible combinations of data versus scale. A scale can be continuous or discrete. Data can be continuous or discrete. Care should be taken when plotting one type of data to a different type of scale. Note the placement of the labels for the names of the months.

Multiple Graphs Using the Same Parameters

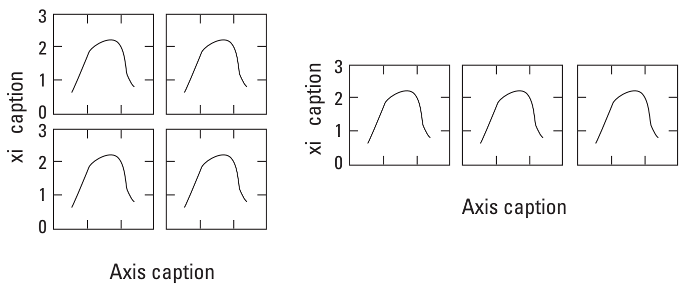


Figure 18. Suggested layout when multiple graphs using the same parameters are displayed in a single figure. If the same parameters are present on several graphs such that they may be grouped or stacked, one *x*-axis caption and one *y*-axis caption may apply to all graphs presented.

Values Along the Bottom and Left Axes

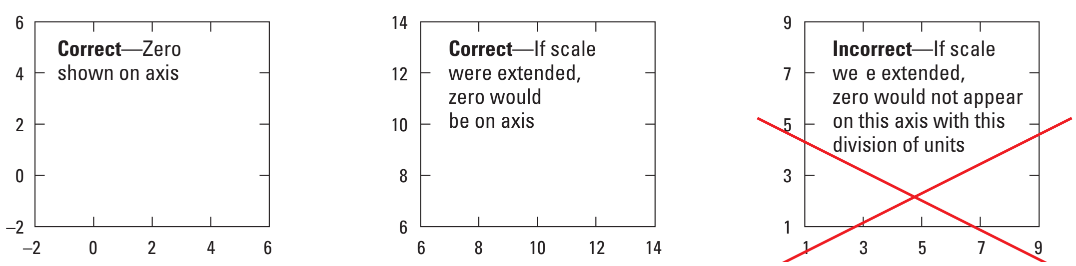


Figure 19. Examples of how to label left and bottom axes on a non-logarithmic graph such that the numeric scale could be extended to the value of zero. When scales on both the left and bottom axes begin with zero, both zeros should be shown at the lower left corner of the graph. Preferred numerical divisions on scales should be 1, 2, 5, or multiples of these basic numbers.

Arithmetic Grids

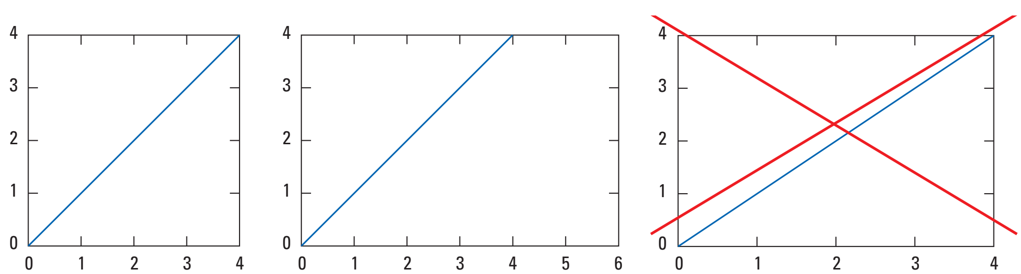


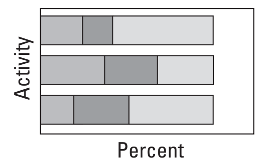
Figure 20. Arithmetic grids must be square to avoid skewing the data.

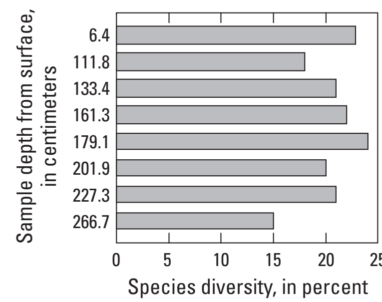
Commonly Used Graphs

General example | Specific example

Bar or Horizontal (Bar) Graph

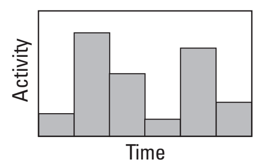
Emphasizes the volume of data. The graph compares data for different items or activities at the same time; therefore, it needs only one numerical scale as no time scale is necessary. The bars representing plotted data should be arranged in order of magnitude, if possible. This type of graph best shows percentages. Do not show ticks on bar axis (*y*-axis in example).

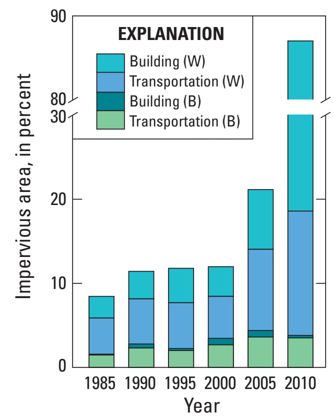




Column or Vertical (Bar) Graph

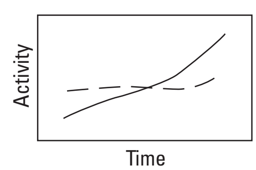
Emphasizes sharply fluctuating magnitudes of data for one item or activity at different times, for different categories (for example, rice, corn, wheat), or for different locations (for example, basins, counties). The bars may be subdivided, by color or patterns, so that component parts of the total are represented by the height of segments of the columns. Do not show ticks on bar axis (*x*-axis in example).

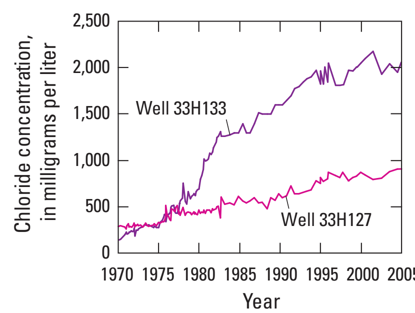




Curve or Line Graph

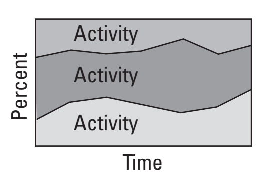
Emphasizes the trend or rate of activity of relatively continuous data. The graph is drawn by connecting, in sequence, plotted points that represent data. Different line symbols or colors are used to distinguish intersecting lines on the graph. If more than three intersecting lines are to be compared, multiple graphs may be necessary. Line graphs can also plot probability or can be duration curves with log-like axes.

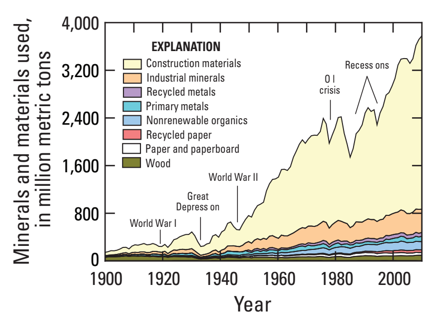




Surface or Band Graph

Emphasizes amount of data. On this graph, values of a number of parts are represented by layers placed one above the other, forming a cumulative total. The graph is especially effective for showing components but should not be used when data fluctuate sharply, thereby distorting other component data.

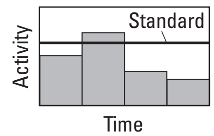


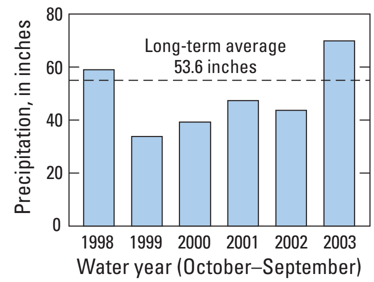


General example | Specific example

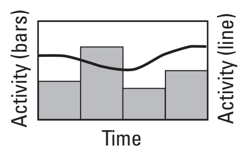
Combination Graph
(Combines two or more of the preceding forms into one graph)

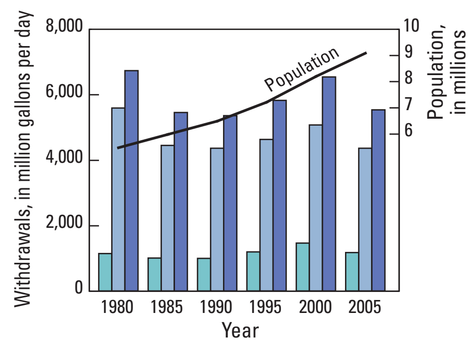
A vertical bar and straight horizontal line combination is useful for measuring performance against a goal or standard, such as showing annual precipitation by bar and average annual precipitation by horizontal line. Do not show ticks on bar axis (*x*-axis in example).



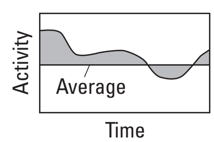


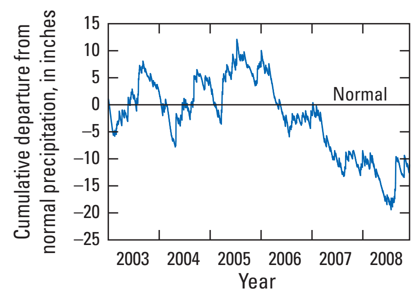
A vertical bar and curve line combination is useful for relating variables such as water use and population, and precipitation and water levels in wells. Do not show ticks on bar axis (*x*-axis in example).



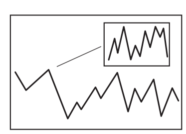


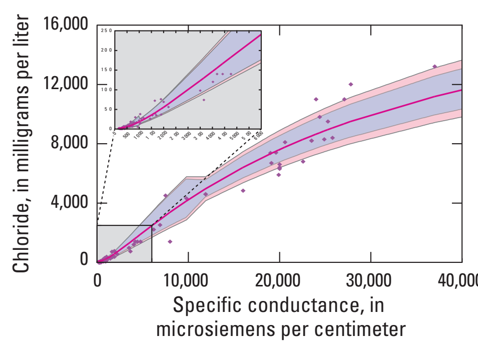
A curve line and straight horizontal line combination can be used to compare monthly or annual precipitation with an average or cumulative departure from average.





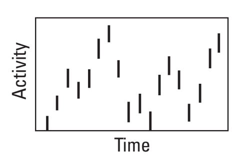
An inset, which is a smaller graph superimposed on a larger one, magnifies part of the data lost in the range of the larger graph. The informative value of this presentation lies in a different or more comprehensive view of the data.

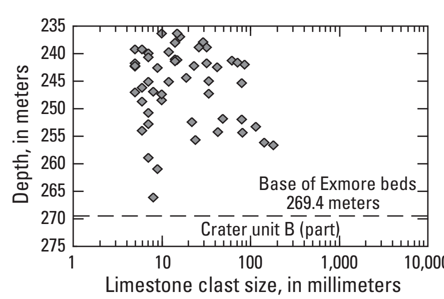




Symbol Graph (Scatterplot)

Emphasizes the general trend or activity of data. Symbols, unconnected by lines, represent data. Example usage could be (1) a series of vertical bars, each bar showing the maximum and minimum values of the data (such as monthly mean water level) for a period of time or (2) symbols plotted as data points, where a trend line is not possible or desired. Dot size needs to be selected on a visual basis. A common practice is to use a dot size where the dots in dense areas just begin to coalesce.

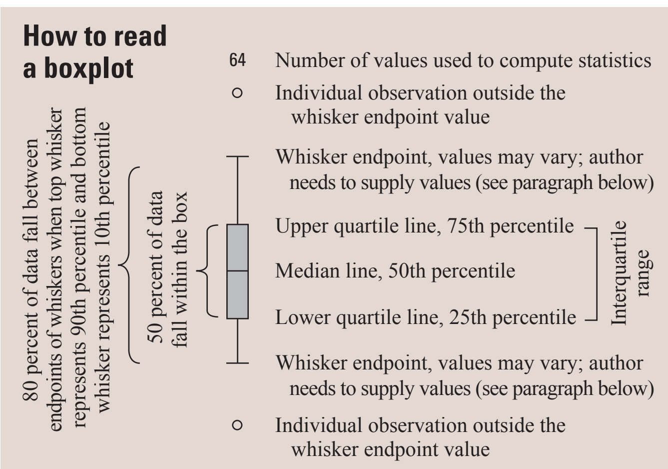




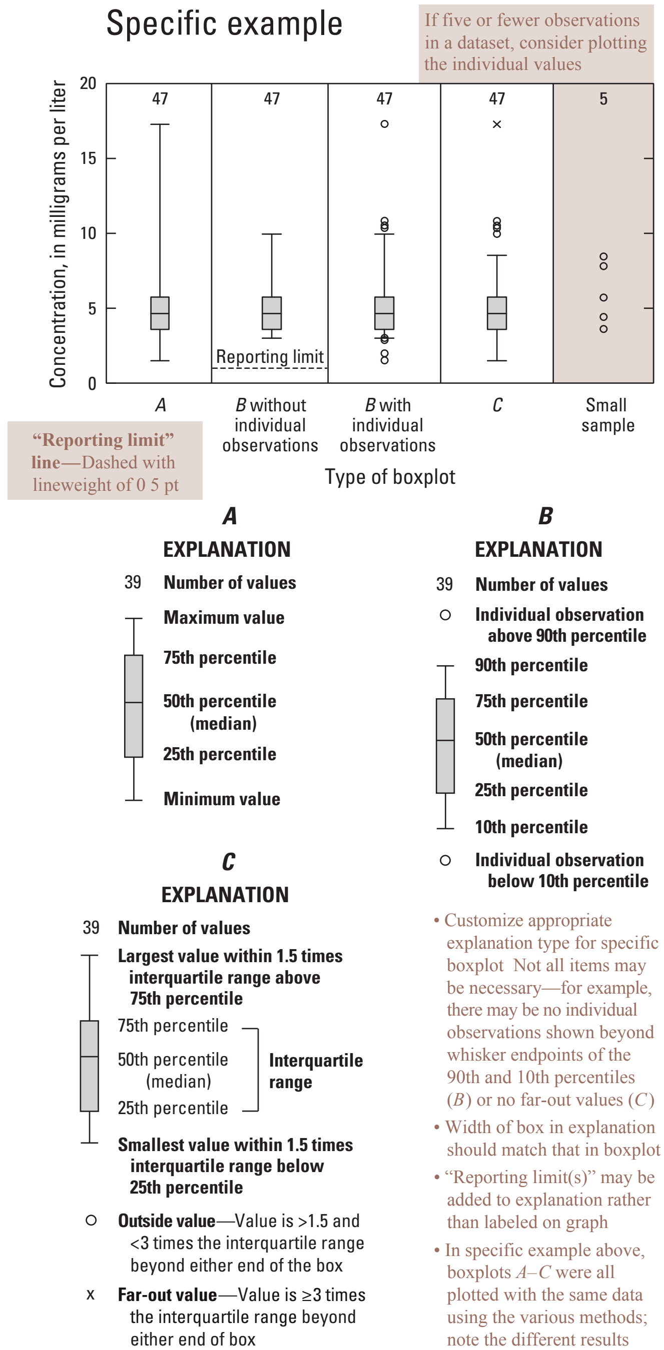
Boxplot

A boxplot (also known as a box-and-whisker diagram or plot) provides a concise visual summary of a large set of numbers by the use of five-number summaries. Boxplots are particularly useful when comparing multiple datasets without having to actually compare each set of numbers. Boxplots display

1. the center of the data (the median line—the center line of the box);
2. the variation of the data (shown by the box and whiskers);
3. the skewness of the data (shown by the asymmetry of the box and whiskers); and
4. the presence or absence of individual observations beyond the whiskers; if none exist in the dataset, the whisker endpoints denote the maximum and minimum values in the dataset (for methods *A* and *C*, see paragraph below).

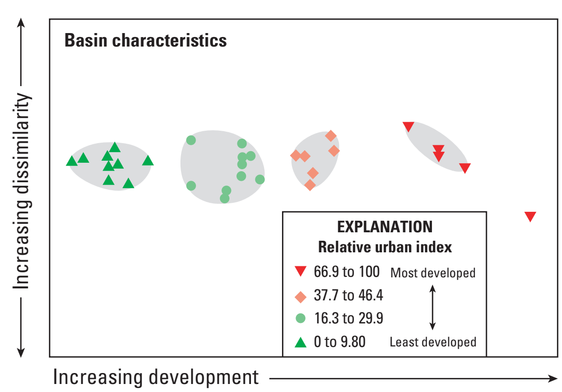


Various methods can be used to create boxplots. In USGS publications, the most common types of boxplots show the top and bottom whisker endpoints as denoting (*A*) maximum and minimum (simple), (*B*) 90th and 10th percentiles (truncated), or (*C*) largest value within 1.5 times the interquartile range above the 75th percentile or smallest value within 1.5 times the interquartile range below the 25th percentile (often called the Tukey boxplot). This last type of boxplot is useful for model-hypothesis test diagnostics, but extremely complicated for a general audience to understand.



Scaleless Graph

Scales on ordination graphs are relative to the data shown and have no absolute value. When general relations between parameters are shown without the use of a grid or scale, arrows must be added to show general direction of increasing amount.



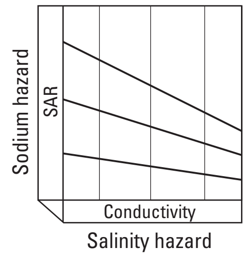
Commonly Used Diagrams

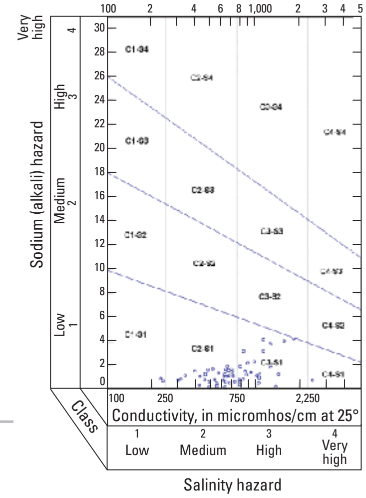
General example

Specific example

Classification of Water for Irrigation Diagram

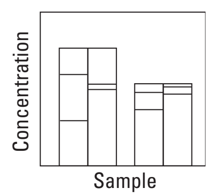
Permits an estimate to be made of the suitability of water for irrigation in terms of sodium and salinity hazards, once the sodium-adsorption ratio (SAR) and the electrical conductivity of the water are known. The diagram is divided into 16 areas that are used to rate the degree to which a particular water may be subject to salinity problems and undesirable ion-exchange effects.

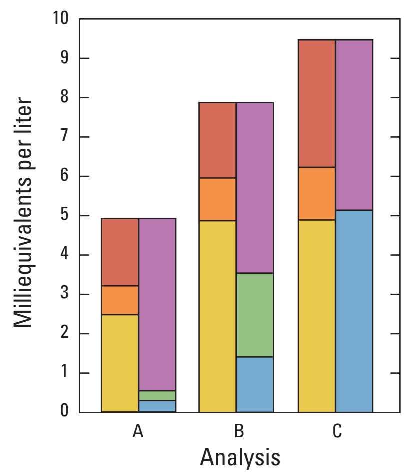




Collins Diagram

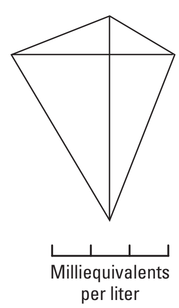
Shows in a bar-graph form the total solute concentration and the proportions assigned to each principal ionic species. Each analysis is represented by a vertical bar graph whose total height is proportional to the total concentration of anions or cations, in milliequivalents per liter. The bar is divided into a left half representing cations and a right half representing anions. Each half is then divided by horizontal lines to show concentrations of the major ions, which are identified by distinctive patterns or colors. The lengths of the cation and anion halves should be equal. The following colors should be used to represent these elements or ions: calcium (Ca), red; magnesium (Mg), orange; sodium (Na), yellow; carbonate (CO_3) and bicarbonate (HCO_3), purple; chloride (Cl), green; sulfate (SO_4), blue.

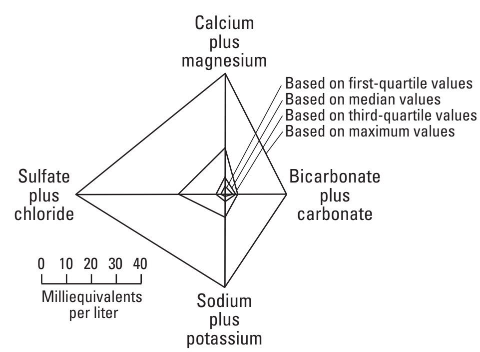




Kite Diagram

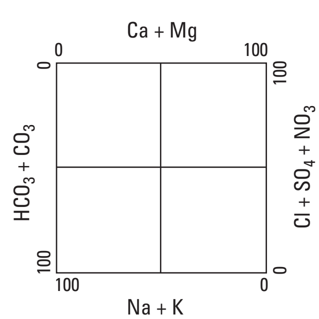
A pattern diagram in which concentrations of cations (vertical lines) and anions (horizontal lines) are represented on rectangular coordinates. The length of each coordinate line from center corresponds to the concentration of constituents, in milliequivalents per liter. Once the ends of the four coordinate lines are connected, thereby forming the distinctive kite shape, the patterns for different water types can be easily and quickly compared visually.





Modified Piper Diagram

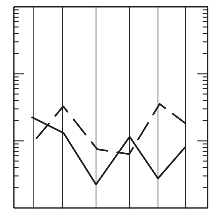
Indicates the essential chemical character of a water sample, or groups of samples, by the location of plotted points within a square diagram. Concentrations of the ions for each water sample are in milliequivalents per liter; points are plotted in percentages of total anions. Thus, the sum of cations (Ca + Mg) + (Na + K) equals 100 percent and the sum of anions equals 100 percent.



General example Specific example

Nomograph Diagram

Can be used to depict one analysis or a group of analyses. Lines connect points on the interior scales of the nomograph that represent concentration of ions, in milligrams per liter. Scales for milliequivalents per liter at the left and right sides of the nomograph give the advantage of showing the relation to scales for milligrams per liter. Waters of similar composition plot as near-parallel lines.



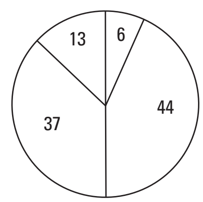
Pie (Circular) Diagram

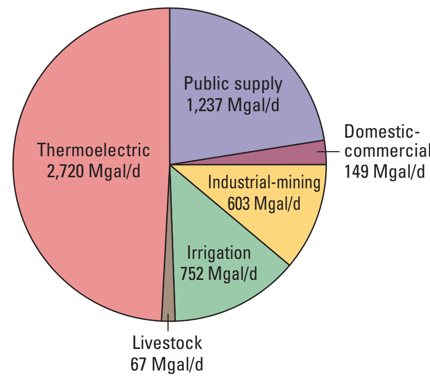
Emphasizes subdivisions of a whole by means of a circle, which is divided into sectors. It is named for its resemblance to a pie that has been sliced. This diagram is commonly used to show percentages (for example, water-use categories), but it can also be drawn with a scale for the radii. The first subdivision should start at "noon," and the rest of the subdivisions should follow in a clockwise manner.

Visual comparison of subdivisions of bar graphs are clearer and more accurate than comparison of sectors of pie diagrams, because the eye can measure linear distances easier than radial ones.

When using colors or gray scale, generally chose the lightest hue for the large pie pieces and a darker hue for the small ones. Do not use the "%" symbol in a pie diagram; spell out the word "percent."

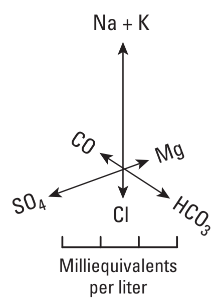
If leadering is necessary, leaders (straight lines without arrowheads) should cross the slice at 90° and point towards the center of the pie. Approximately one-third of the leader should be shown inside the pie slice.





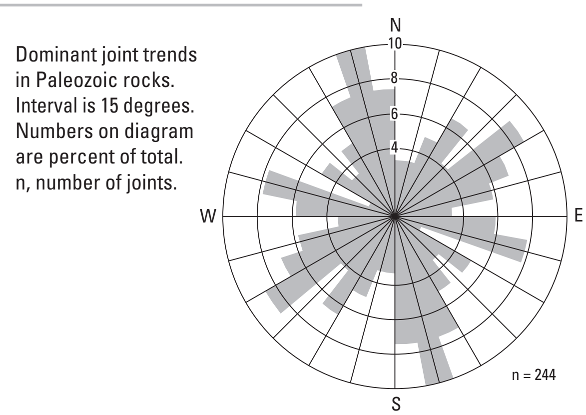
Radiating-Vector Diagram

Uses a system of plotting analyses by radiating vectors. The length of each of the six vectors from the center represents the concentration of principal ionic species, in milliequivalents per liter. A scale of units must be included with each diagram. A summation of the lengths of the arrows for cations should equal the lengths for the anions.



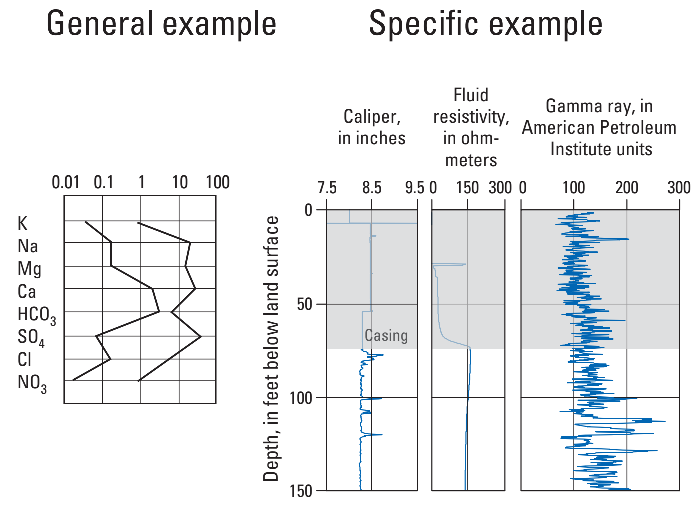
Rose Diagram (Compass Rose)

A circular or semicircular star-shaped graph indicating values or quantities in several directions of bearing, consisting of radiating rays drawn proportional in length to the value or quantity. On geologic maps or diagrams, it may be used to show alignment of structures such as faults and joints.



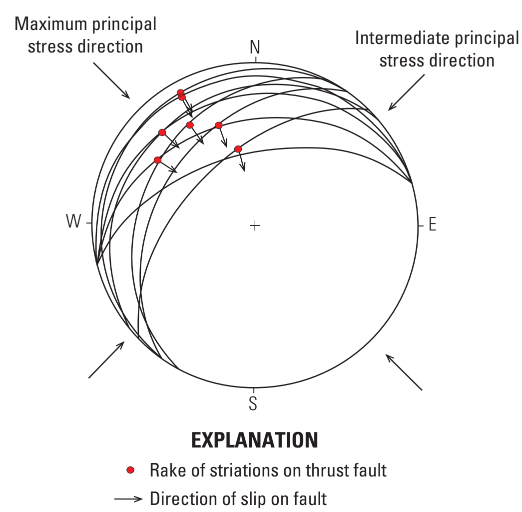
Semilog Concentration Graph

Consists of a principal graph on which is a set of parallel horizontal log-scale axes, each corresponding to a selected constituent or variable. On each axis are plotted the distribution, minimum, mean, and maximum values for the variables selected. Straight lines are drawn to connect the low values and the high values for all variables, thereby giving a characteristic shape to the "distribution" of a selected group of data. An optional top-view graph contains a horizontal log scale corresponding to the principal graph; the vertical scale can be a time or space (for example, below land surface) scale depending on the variable selected. Taken together, the principal graph and the top-view graph represent front and top orthographic projections of a three-dimensional array of data.



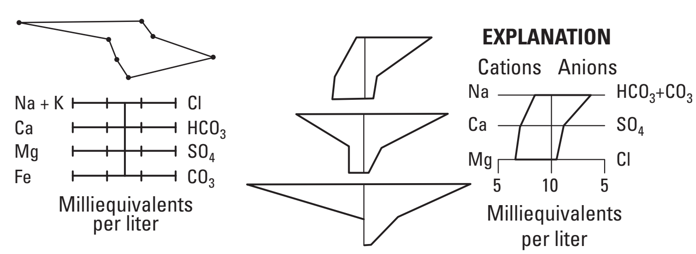
Stereographic Projection

A projection used in optical mineralogy and structural geology, made on an equatorial plane (passing through the center of the sphere) with the point of projection at the south pole. Center point is shown by a "+" and, at the very least, north (N) is ticked at the top of the circle. Showing east (E), south (S), and west (W) are optional.



Stiff Diagram

Forms a relatively distinctive pattern than can be used to show water composition differences or similarities. Four parallel horizontal lines extending on each side of a vertical line form a grid on which cations are plotted to the left and anions are plotted to the right. The plotted points are connected by lines, forming a closed pattern that is characteristic of a certain water. The pattern tends to maintain its characteristic shape as the sample becomes dilute. The width of the pattern is an approximate indication of total ionic content.



Triangular and Trilinear Diagrams

Shows a percentage composition in terms of relative amounts of three components.

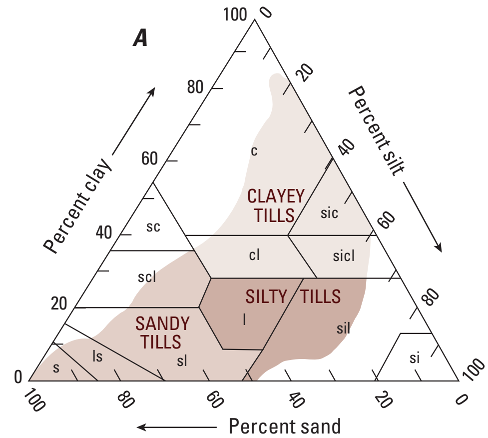
Ternary Diagram (*A*)

A triangular diagram that graphically depicts the composition of a three-component mixture or ternary system. An example is an AFM diagram, which shows the simplified compositional character of a metamorphosed pelitic rock by plotting molecular quantities of the three components: A = Al_2O_3; F = FeO; and M = MgO.

Piper (Trilinear) Diagram (*B*)

Indicates the essential chemical character of a water by single-point plottings of cations and anions on trilinear coordinates. The proportions of cations and anions are plotted in each of the lower triangles; then the points are extended into the central diamond-shaped field. The intersection of the projections represents the composition of the water with respect to the combination of ions shown. An alternative to adding the words “in percent” to each of the eight axis captions (for example, “Magnesium, in percent”) is to uppercase “percent,” thus effectively assigning it a higher rank.

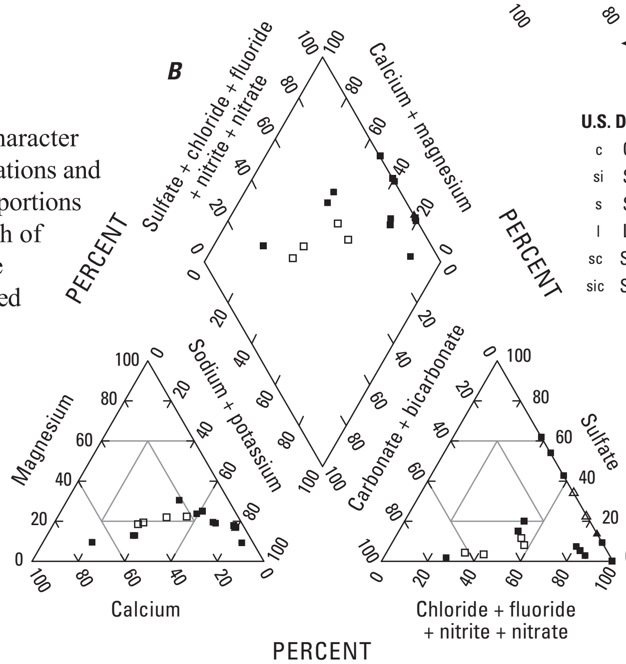
Specific examples

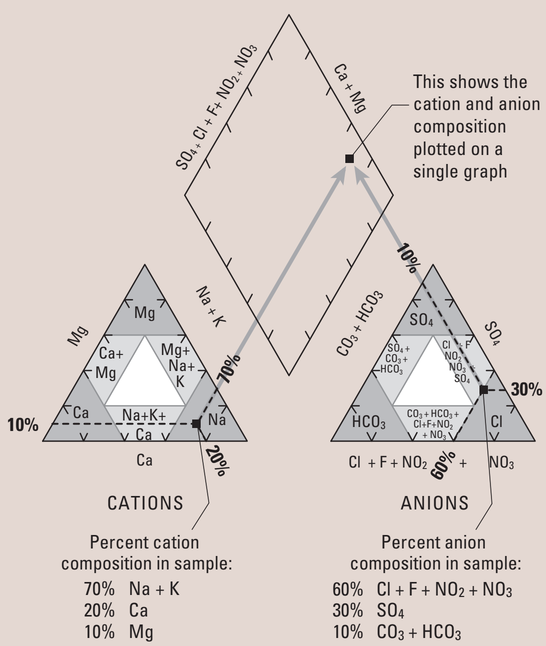


EXPLANATION

U.S. Department of Agriculture soil textures

c	Clay	scl	Sandy clayey loam
si	Silt	sicl	Silty clayey loam
s	Sand	cl	Clayey loam
l	Loam	sil	Silty loam
sc	Sandy clay	sl	Sandy loam
sic	Silty clay	ls	Loamy sand





How to read a trilinear diagram

Hydrochemical facies

- Dominant cation or anion
- Dominant cations or anions
- Mixed—No dominant cations and (or) anions

Chemical abbreviations

Bicarbonate	HCO_3	Sulfate	SO_4
Calcium	Ca	Magnesium	Mg
Carbonate	CO_3	Nitrate	NO_3
Chloride	Cl	Nitrite	NO_2
Fluoride	F	Potassium	K
Sodium	Na		

Trilinear diagrams (similar to Piper, 1944) are useful in determining which samples have similar major-ion compositions (Hem, 1985, p. 178). Trilinear diagrams have relative percentages of major cations plotted on the lower-left triangle and relative percentages of major anions plotted on the lower-right triangle. These percentages are projected onto the diamond above. A straight line between two points in any sector of a trilinear diagram indicates the ionic proportions of all possible simple mixtures of waters represented by the two endpoints of the line. Generally, a cation or an anion is considered dominant when its relative proportion to the sum of cations or anions is greater than or equal to 60 percent. When water is designated as having "no dominant anion or cation," nearly equal proportions of major ions are present and it has a "mixed" hydrochemical facies (Katz, 1992). Figure modified from Frick and others (2002).

Maps

Introduction

Large geographic area equals small scale, and small geographic area equals large scale.

Imagine trying to describe the information portrayed in a page-size map using words only. For example, in the map shown on page 80, describing the location of the Kvbt unit might read something like this: "The unit extends south and southwest of the town of Canyon Ferry, up the Missouri River for 30 miles to the edge of the quadrangle in a belt that is less than 5 miles wide and is bounded by faults—a normal fault to the southwest and a thrust fault to the northeast," and on and on. This narration does not even begin to clearly describe the location of that unit.

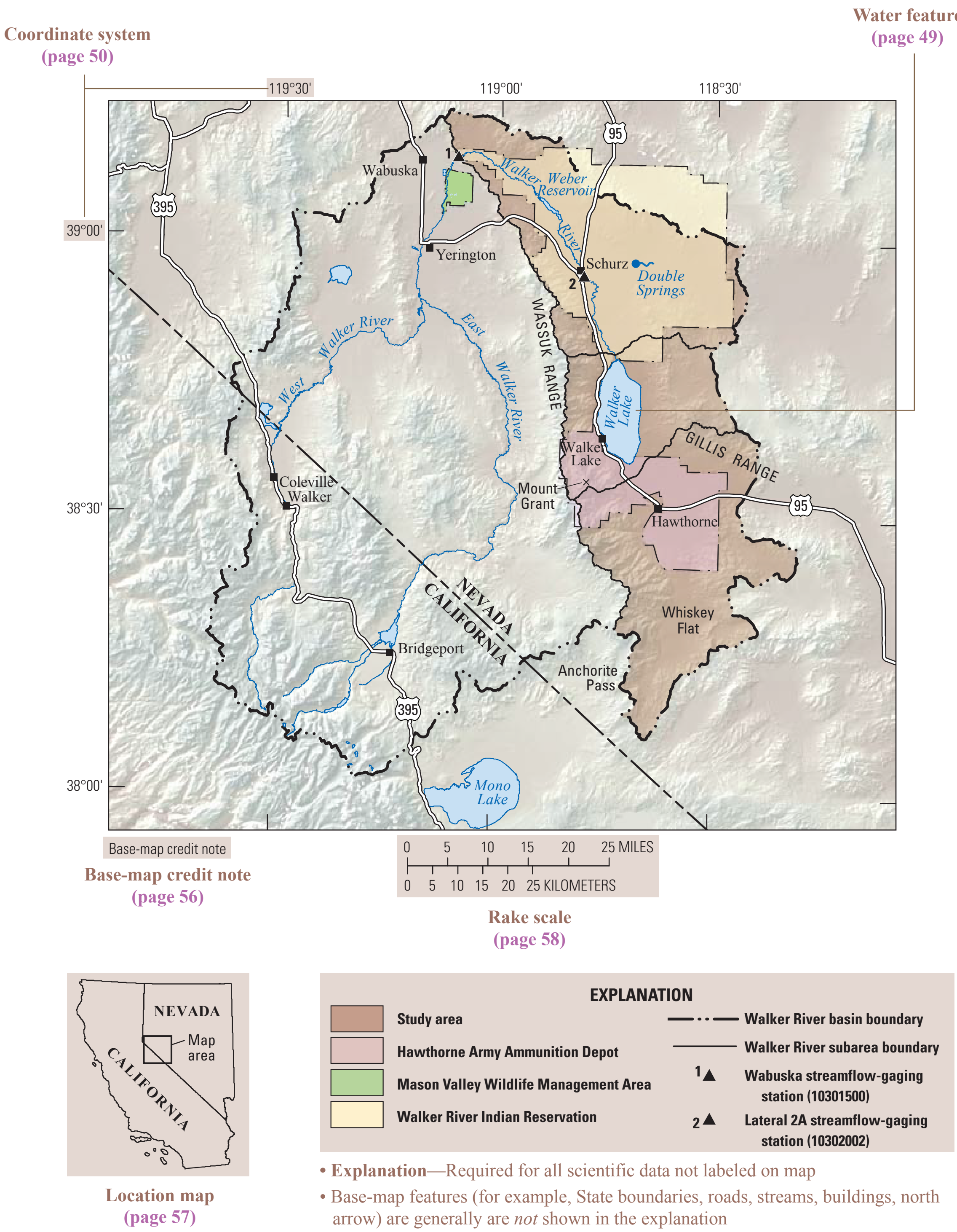
That's the power of technical illustration—the ability to portray with color and labels and carefully placed symbols a visual representation of, for example, the geology that crops out on the surface of the Earth.

The vastly expanded section about page-size maps (pages 48–75) was completely reorganized from version 1 of the standards. The section leads off with figure 21, a map showing basic elements with associated page numbers directing the reader to detailed specifications. To help prepare map figures, a quick guide of topics (listed alphabetically) is shown on the following page. In this new version of the standards, the term "land grid" has been replaced with "coordinate system." Latitude-longitude, Universal Transverse Mercator (UTM), and State Plane—three coordinate systems often used in USGS information products—are discussed. Although it is not a coordinate system, the Public Land Survey System—known as township and range—also is discussed. Entire pages are devoted to base-map credit notes, location maps, and rake scales including how to calculate them from two lines of latitude. Years ago, Neil Maxfield put together a brochure on how to place type on maps. The information shown in the brochure is included in its entirety with some updated graphics. Depression contours are described, and a tip for creating the hachures is included. A section has been added titled "Guidance on Release of Sensitive Water-Related Information," which includes an excerpt from a memo from the Office of Water Information. Numbering systems for wells, springs, and miscellaneous sites are presented. Visual variables and classes of symbols are touched on. Remember this phrase: "large geographic area equals small scale, and small geographic area equals large scale," further explained herein. Simplified map projection information is shown. A two-page spread titled "Geodetic Datums," which includes a discussion of datums used in USGS information products, has been added.

Leading off the "Examples of Maps" section (pages 76–91) are two small-scale maps that have been used in circulars and fact sheets. Other examples include a map placed across a gutter on two pages and the same map shown sidetitle, multiple maps on one page, and maps underlain by shaded relief. On the maps, different colored type is used to highlight various features: "blue" drainage labels, "red" mile marker labels, "white" change in pumpage value labels, and "halo"ed site facility labels. Layout options, in all their variety, are presented. Note, however, that in all of the examples, the neatline does not extend beyond the border of map data.

When creating a page-size map, keep in mind that you are trying to display data, not display design. Good map design does not stand out when it is good; but poor map design stands out when it is not good!

General Information for Maps



- **Explanation**—Required for all scientific data not labeled on map
- Base-map features (for example, State boundaries, roads, streams, buildings, north arrow) are generally are *not* shown in the explanation
- Any base-map feature that might not be recognized should be labeled on the map (if only a few occurrences) or added to the figure explanation (if many occurrences)
- See "Explanation" section for details (page 28)

Figure 21. An example of a map for use in page-size illustrations. Credits for maps used from a previous report should be shown in the figure caption. Figure modified from Allander and others (2009).

Quick Guide

The following information in these guidelines can be used for finalizing maps

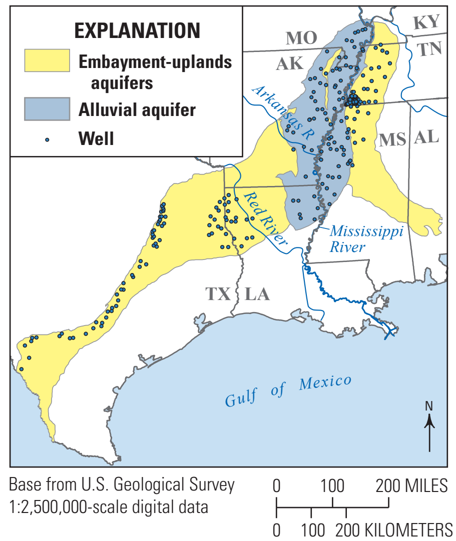
Additional general cartographic information found in these guidelines

Water Features

[0.5-pt lineweight for drainage features (see table 4); C, cyan; M, magenta; K, black]

	4-color	2-color	Black and white
Fill	20% C; 5% M	20% C	20% K
Stroke	100% C; 60% M	100% C	Varying percentages of K
Text	Times New Roman Italic, 7–9 pt (see table 1), same color as stroke		

When Abbreviations Are Used on a Map

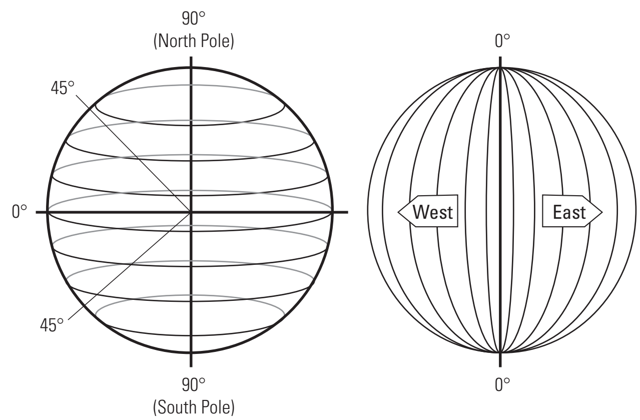


Base from U.S. Geological Survey 1:2,500,000-scale digital data

Ideally, the names of all items labeled on a map—political, geographic, and drainage related—are spelled out. However, when space is an issue, use postal abbreviations for State names and abbreviate drainage feature names (for example, Arkansas R for Arkansas River; S Fk Peachtree Cr for South Fork Peachtree Creek). Punctuation in geographic and drainage features is not shown on a map because a period or an apostrophe could be confused with a data point. Examples of feature names when punctuation should not be used include St Johns River [Fla.], Mt St Helens [Wash.], and St Paul [Minn.].

Coordinate Systems

- A coordinate system is a way to reference, or locate, everything on the Earth's surface in *x*- and *y*- space
- Almost all maps should show an evenly spaced coordinate system. Examples include latitude-longitude grids (see below) or State-developed grids (see p. 53). Township and range grids (see p. 54) also may be shown in addition to a coordinate system. Location maps, maps depicting very small geographic areas (large scale), and maps showing the conterminous United States (often used in figures for USGS circulars) do not require a coordinate system
- For legibility, use only grid ticks at map edges and not grid lines
- Coordinates should be set in Univers 47 Condensed Light, 7 point (table 1). For latitude-longitude coordinates, use degree symbols (°) and straight single (') or double (") quotation marks (prime symbols), not "curly" quotes. See page 51 for use of directional abbreviations
- Maps should be oriented, when possible, such that north is at the top of the page, as that orientation results in a square grid with ticks shown directly across from each other
- When no coordinate system is shown, a north arrow should be included, except on location maps where no north arrow is needed
- Only maps oriented such that north is not at the top of the page should have both a north arrow and a coordinate system



Latitude
Ranges from 0° at the Equator to 90° north or south at the poles

Longitude
Ranges from 0° at Greenwich, U.K., to 180° east or west at the international dateline

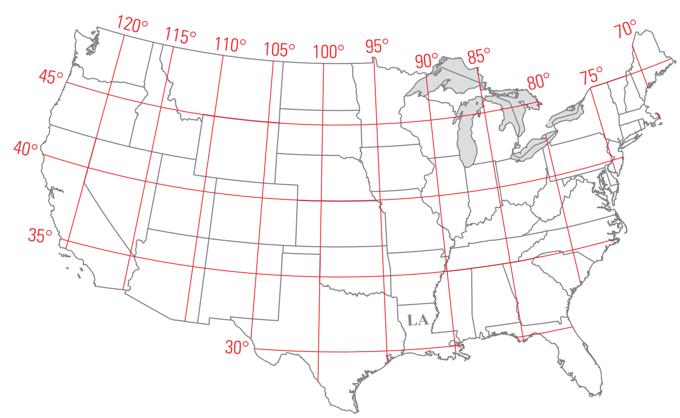
Geographic Coordinate System (Latitude-Longitude Grid)

Latitude is the angular distance, measured in degrees, north or south from the Equator (*x*-axis). The Equator is at 0° latitude, and the North and South Poles are at 90° latitude (see diagrams at upper right). Thus, latitude lines (parallels) are horizontal or subhorizontal, depending on the map projection. Because the United States is located in the Northern Hemisphere, latitude values increase to the north (see map at lower right).

Longitude is the angular distance, measured in degrees, east or west of the Standard or Prime Meridian (*y*-axis), which passes through the Royal Observatory, Greenwich, United Kingdom. Longitude ranges from 0° at the Prime Meridian to 180° at the international dateline, in either direction (east or west). Thus, longitude lines (meridians) are vertical or subvertical, depending on the map projection. Because the United States is located west of the Prime Meridian, longitude values increase to the west (see map at lower right).

Choosing the Interval Between Ticks

A minimum of two latitude and two longitude ticks is preferred. If the map area includes the international dateline or the Equator, or shows well or streamgage locations, two of each are required. If two or more latitude and longitude ticks are shown on a page-size map, the same interval must be applied to both. For example, if the latitude coordinates are labeled 45°00' and 45°30', then the longitude coordinates are labeled 110°00' and 110°30'.



Latitude-longitude grid for the conterminous United States. Red grid is shown here for reference only—this map may be used to confirm that the coordinates of a map area shown in a page-size figure are approximately correct. For example, a map showing an area in Louisiana (LA) should have latitude values between 28° and 34° and longitude values between 88° and 95°.

If a coordinate system is shown in a page-size map figure, only grid ticks at map edges (and not grid lines) should be used.

Remember that location maps, maps depicting very small geographic areas (large scale), and maps showing the conterminous United States (often used in figures for USGS circulars) do not require a coordinate system.

Adding Directional Abbreviations

When two latitude and two longitude coordinates and their corresponding ticks are shown on a map of the conterminous United States, readers can orient themselves; therefore, directional abbreviations need not be shown. However, if requested by the author or the editor, directional abbreviations may be shown. When the map area is outside of the conterminous United States, each coordinate should be followed by a directional abbreviation, which is always preceded by a space (see map at right). On a page-size map, no period follows the directional abbreviation (for example, 110° W). In the text of the report, however, a period does follow the directional abbreviation (for example, 110° W.).

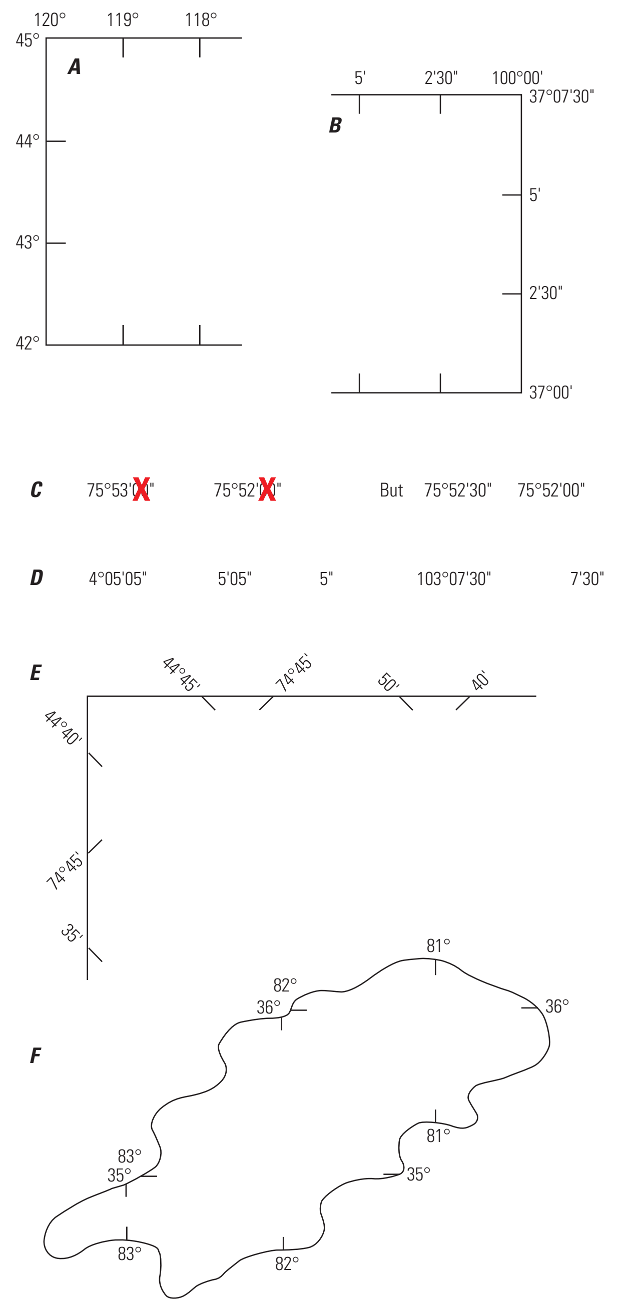
Labeling Latitude-Longitude Ticks

Latitude and longitude ticks should be the same lineweight as the neatline (0.5 point or 0.175 mm). Note that tick length should be 7.2 points (2.54 mm or 0.10 inch) for labeled ticks and 3.6 points (1.27 mm or 0.05 inch) for unlabeled ticks.

Latitude and longitude coordinate labels should be placed outside the neatline of the figure and should be centered on the grid ticks. Coordinate values should be added with the following rules kept in mind:

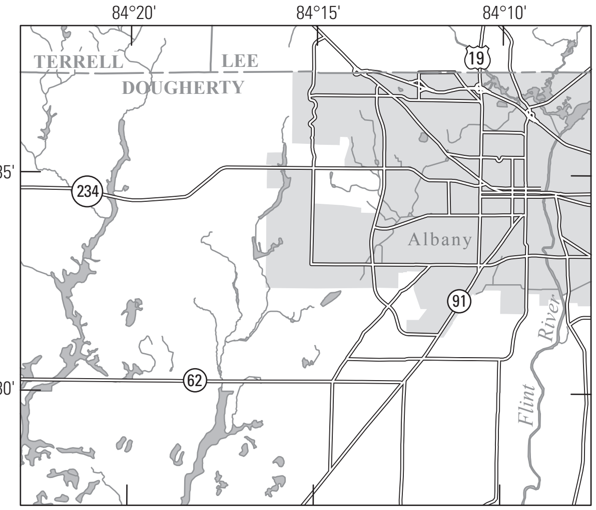
1. When geographic projections are divided into multiples of full degrees, minute (00') values are not used after the degree values (*A*).
2. When geographic projections are divided into units of less than full degrees, degree values may be used on the coordinates at or nearest the corners of the map and where the degree value changes and omitted from other coordinates (*B*).
3. Zero-second (00") values are never used when all coordinates have 00" values (*C*).
4. When values for minutes or seconds are less than 10, a zero is used before the number only when that number is preceded by degrees or minutes (*D*).
5. If a large-scale map is oriented such that north is not at the top of the page, the coordinate labels should be aligned in the same direction as the ticks (*E*). However, coordinate labels for small-scale maps, such as a world map, should be aligned with the map border (neatline), square to the page (see fig. 33 on page 76).
6. If a map has an irregular shape and the reader might have difficulty discerning which coordinate values go with which ticks, the values may be retained on all ticks.

   This example (*F*) shows ticks extending into the amoeba-shaped map area. In some circumstances, it may be necessary to show ticks on the outside of an irregularly shaped map area if placing the ticks on the inside makes them difficult to see (see fig. 15*A* on page 31).



7. Latitude and longitude ticks should be labeled along the top and left sides of page-size or smaller maps (*G*). For larger maps (such as those occupying a two-page spread), latitude and longitude coordinates should be shown on all four sides.

G

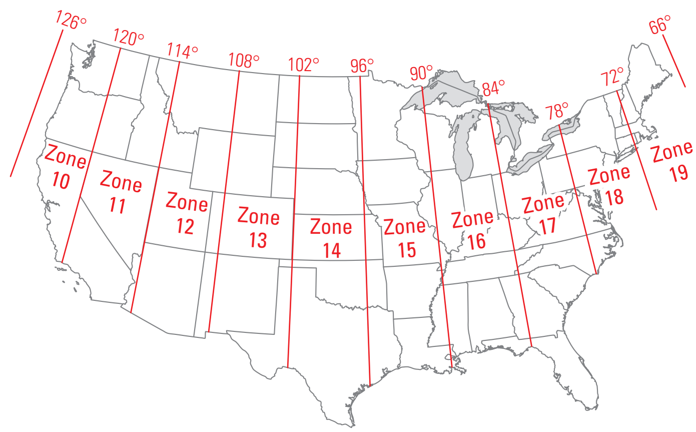


Universal Transverse Mercator Coordinate System

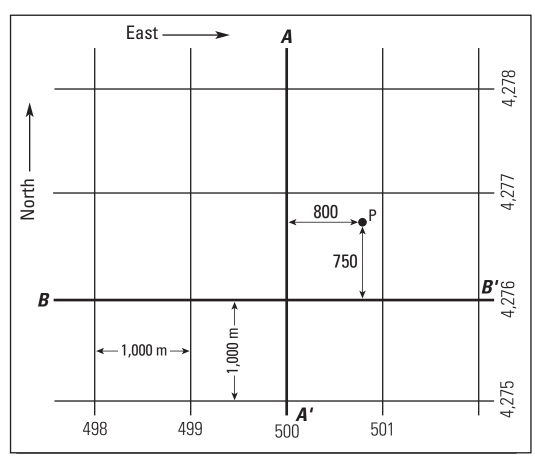
To simplify the use of maps and to avoid the inconvenience of pinpointing locations on curved reference lines, a rectangular grid consisting of two sets of straight, parallel lines, uniformly spaced, each set perpendicular to the other was adopted in 1936 by the National Geospatial Intelligence Agency (NGA; formerly National Imagery and Mapping Agency). The Universal Transverse Mercator coordinate system (grid), commonly referred to as UTM, is based on the Transverse Mercator projection. The grid covers most of the planet except the polar regions. In this grid, the world is divided into 60 north-south-trending zones, each 6° wide in longitude. These zones are numbered consecutively beginning with Zone 1, between 180° and 174° west longitude, and progressing eastward to Zone 60, between 174° and 180° east longitude. Thus, the conterminous United States is covered by 10 zones (see map at right). Virtually all NGA and USGS topographic maps and many aeronautical charts show UTM grid lines or ticks.

In each zone, coordinates are measured as northings and eastings in meters (see diagram at right). The northing values are measured from zero at the Equator in a northerly direction. The central meridian *in each 6° zone* is assigned an easting value of 500,000 meters. For example, in Zone 16, the central meridian is 87° W. One meter east of that central meridian is 500,001 meters easting. Because UTM coordinates are not unique, the correct zone must always be listed when giving UTM coordinates. Text modified from U.S. Geological Survey (2001).

If latitude-longitude and UTM ticks are shown on the same map, label latitude-longitude coordinates on the top and left of the map and label UTM coordinates on the right and bottom of the map. If there is a space issue, UTM coordinates may be rotated 90° counterclockwise.



Universal Transverse Mercator (UTM) zones for the conterminous United States.



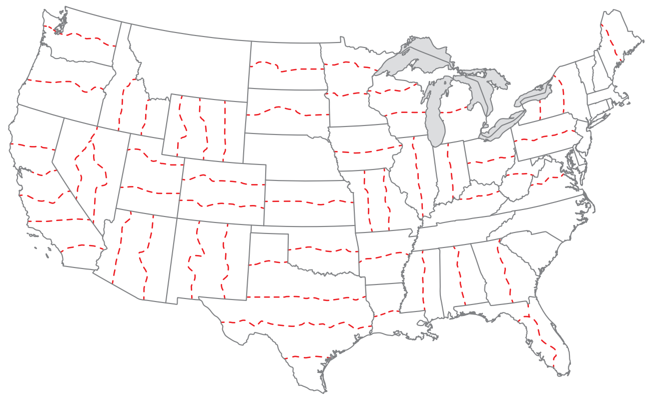
UTM coordinates in thousands of meters. The grid coordinate of line *A–A'* is 500,000 meters east. The grid coordinate of line *B–B'* is 4,276,000 meters north. Point P is 800 meters east and 750 meters north of the grid lines; therefore, the UTM coordinates of point P are north 4,276,750 and east 500,800. Figure modified from U.S. Geological Survey (2001).

State Plane Coordinate System

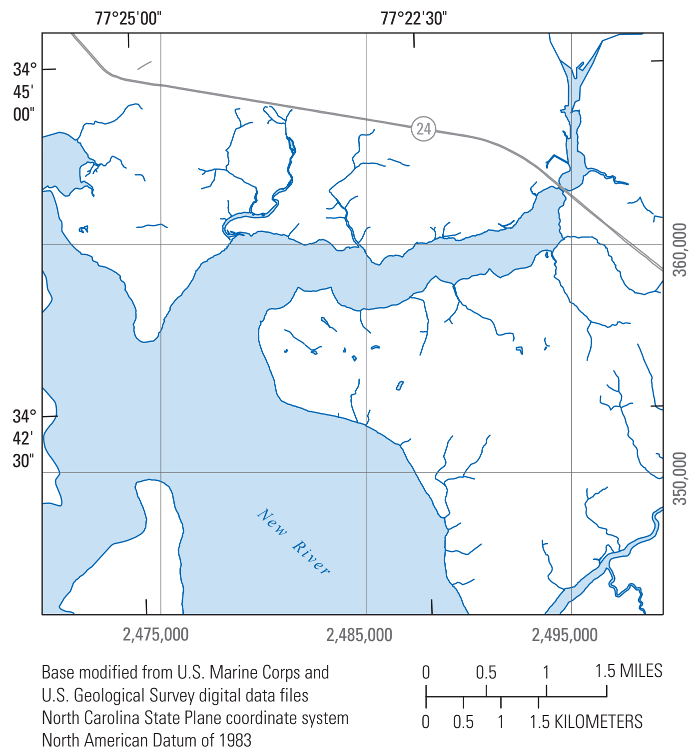
The State Plane Coordinate System (SPCS), used for large-scale mapping in the United States, was established in the 1930s by the U.S. Coast and Geodetic Survey (renamed the National Geodetic Survey). This system is actually a series of separate systems (about 120 State Plane zones), each covering a State or part of a State (see map upper right), the boundaries of which usually follow county lines. Each zone has its own central meridian or standard parallel. The Lambert Conformal Conic projection is used to map States that are wider than they are tall (for example, Washington and Pennsylvania). The Transverse Mercator projection is used to map States that are taller than they are wide (for example, Idaho and Illinois).

The SPCS is popular with State and local governments because it is highly accurate within each zone and uses a simple Cartesian coordinate system (x, y) to specify locations rather than a more complex spherical coordinate system (for example, latitude and longitude). By ignoring the curvature of the Earth, "plane surveying" methods can be used, speeding up and simplifying calculations. The system has a maximum linear error of 1 in 10,000 and is four times as accurate as the UTM system. Outside a specific State Plane zone, accuracy rapidly declines; thus, the system is not useful for regional or national mapping.

The Cartesian coordinate system is created for each zone by establishing an origin point some distance (usually 2,000,000 feet) to the west of the zone's central meridian and some distance to the south of the zone's southernmost point. Location of this point ensures that all coordinates within the zone are positive (see map lower right). Distances from the origin point are generally measured in feet but sometimes are measured in meters. The x-distances are typically called eastings because they measure distances east of the origin. The y-distances are typically called northings because they measure distances north of the origin. Text modified from http://education.usgs.gov/lessons/coordinatesystems.pdf.



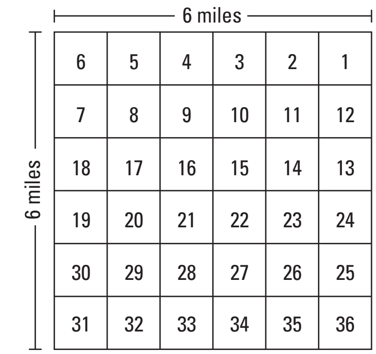
State Plane Coordinate System consisting of about 120 State Plane zones for the conterminous United States.



Example of a map showing both latitude-longitude and UTM grids and coordinates. Note, UTM grid lines are shown using a thin lineweight and screened to differentiate them from latitude-longitude ticks. Also, the UTM coordinate system is shown in the base-map credit note.

Public Land Survey System (Township and Range)

The Public Land Survey System (PLSS)—also known as township and range—is used in about one-half of the States. It was designed in the early history of the United States for the surveying of public lands, mainly in the Midwest and the West. This surveying system is now used in the surveying of private lands also. It is *not* a coordinate system. Each State and territory is assigned to a region whose initial survey point is defined as the intersection of a principal meridian and a base line (see fig. 22). A region may cover an entire State, a part of that State, or many States. Each region is subdivided into townships, areas that are approximately 36 square miles, 6 miles on a side. Each township is subdivided into 36 sections, 1 mile on a side. Sections are subdivided into quarters, quarters are subdivided into quarter quarters, and so on.



Sections within a township numbered sequentially from the northeastern corner to the southeastern corner

Numbering System

The tiers of townships are numbered consecutively north or south of the base line as “Township 1 North, Township 2 North, Township 1 South, and so forth.” The rows of ranges are numbered consecutively east or west of the principal meridian as “Range 1 East, Range 2 East, Range 1 West, and so forth.” Each section (approximately 1 square mile) within a township is numbered sequentially from the northeastern corner to the southeastern corner (see diagram upper right). The District of Columbia and the States, Commonwealths, and territories listed to the right do not have township and range grids.

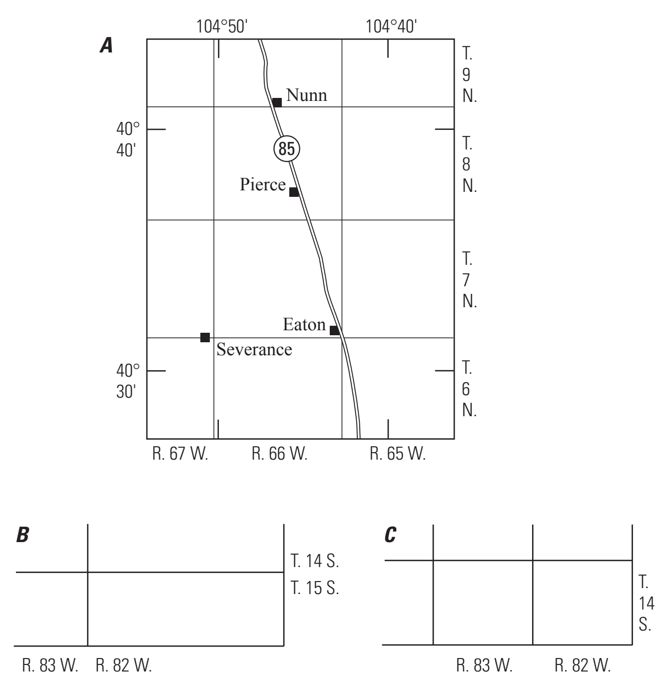
Political entities that do not have township and range grids

Connecticut	Massachusetts	Rhode Island
Delaware	New Hampshire	South Carolina
District of Columbia	New Jersey	Tennessee
Georgia	New York	Texas
Guam	North Carolina	Vermont
Hawaii	Ohio (parts)	Virgin Islands
Kentucky	Pennsylvania	Virginia
Maine	Puerto Rico	West Virginia
Maryland		

Labeling Township and Range Grid

A latitude-longitude grid, used in conjunction with a township and range grid (where available and when used), is recommended.

1. Township and range labels should be set in Univers 47 Condensed Light, 7 point, all uppercase (table 1); lines should be 0.3 point or 0.106 mm (table 4). Township and range labels and lines may be shown in 50 percent black, especially if other base-map information is shown in 50 percent black.
2. When a township and range grid is shown on a map, township labels should be located along the right side of the map and range labels should be located along the bottom of the map (*A*).
3. Township and latitude labels may be stacked (left justified) when space is at a minimum. Do not stack “range” or “longitude” labels (*A*).
4. On maps where the township and range grid is widely spaced, the township and range labels should be set on opposite sides of the boundaries (*B*). On maps where the grid is narrowly spaced, the township and range labels should be centered between the township and range boundaries (*C*).
5. Township and range labels appearing outside the body of the map should include periods after the letter designations and one space in between letters and numbers (for example, T. 14 S. and R. 83 W.); labels appearing inside the body of the map should not include periods after the letter designations (for example, T 14 S and R 83 W).



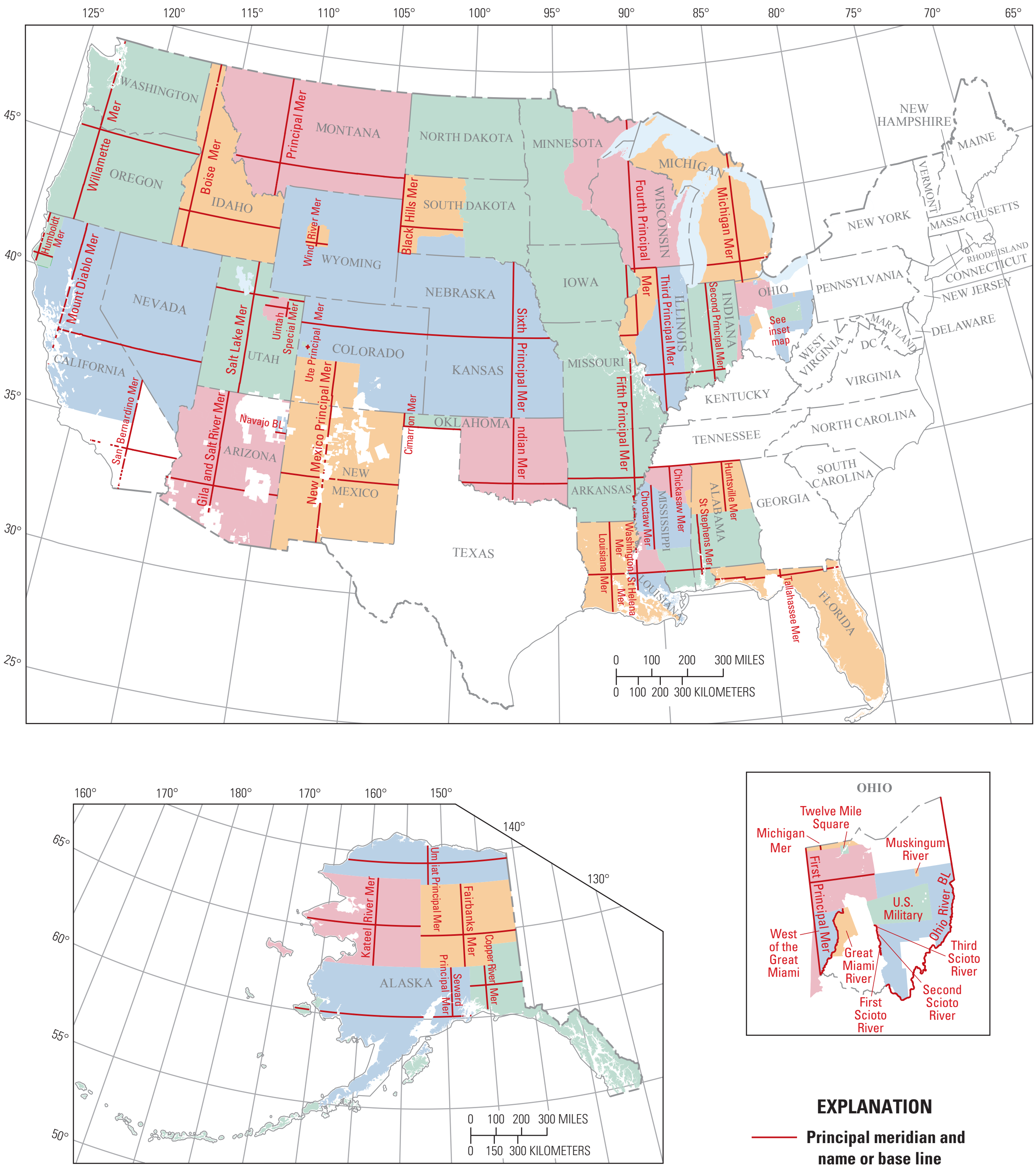


Figure 22. Principal meridians and base lines of the U.S. system of rectangular surveys (Public Land Survey System, or PLSS). Each colored area represents the extent of public-land surveys on the basis of the principal meridian and base line indicated in that area. Areas shown in white are not covered by the PLSS. These areas include States, territories, Indian reservations, early land grants, military reserves, and other lands. Mer, meridian; BL, base line. Source: *National Map* at http://nationalmap.gov/small_scale/a_plss.html.

Base-Map Credit Note

- Not required for location maps, sketch (cartoon-like) maps, or generalized maps
- Not required for maps having bases that consist of only a coordinate system. Generally, if culture names, topographic contours, drainage, or roads are shown, base-map credit notes are given
- Required for a map generated by scanning a published map. List source (agency name); name, scale, and date of scanned map
- Required for a map generated from digital data. List source (agency name), scale of original digital data, and date (if known)
  - Additional information may be included but is not limited to:

    Map projection name and zone (if applicable)

    Map standard parallels (if applicable)

    Central meridian (if applicable)

    Horizontal datum (if applicable)

    (Vertical datum is usually associated with specific data, such as potentiometric contours, shown in a figure, and the datum should be specified in the explanation, see page 29)

Official datum name	Abbreviation
Horizontal	
North American Datum of 1927	NAD 27
North American Datum of 1983	NAD 83
World Geodetic System of 1984	WGS 84
Vertical	
National Geodetic Vertical Datum of 1929	NGVD 29
North American Vertical Datum of 1988	NAVD 88

- For guidance on how to credit the use of ArcGIS, Google Maps and Google Earth, OpenStreetMap, and Bing Maps, go to http://internal.usgs.gov/publishing/toolboxes/gisguidance html
- Should be placed beneath lower left corner of map
- Should use Univers 47 Condensed Light, 7 pt, left justified. Make first line longer than succeeding lines, where possible
- Should begin with the words “Base from” or “Base modified from”
- Should be self-contained and give adequate information without the need to direct readers to the section listing references

Base map generated from data scanned from published maps and modified using illustrating software:

Base modified from U.S. Geological Survey
Saint Peter, 1:24,000, 1992

Required base-map credit information for maps generated from digital data:

Base modified from U.S. Geological Survey
1:250,000-scale digital data

Additional information that may be included in base-map credit information for maps generated from digital data:

Base map generated from Digital Line Graphs

Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-Area Conic projection
Standard parallels 29°30' N. and 45°30' N.
Central meridian 96°00' W.
North American Datum of 1983

Base map generated from USGS 1:100,000-scale quadrangle modified and published to match a published 1:500,0000-scale State base map

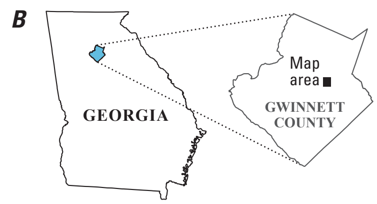
Base from U.S. Geological Survey [State name] State base map, 1:500,000
digital data, [year], [quadrangle name], 1:100,000, [quadrangle year],
Lambert Conformal Conic projection, standard parallels 33° N. and 45° N.,
central meridian 90° W.

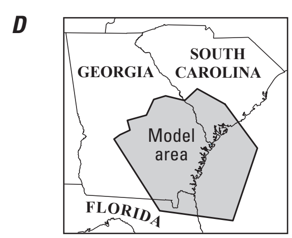
Shaded-relief base map generated from elevation data

Base from U.S. Geological Survey National Elevation
Dataset 30-meter digital elevation model showing
land-surface elevations shaded at 2-meter intervals

Location Map

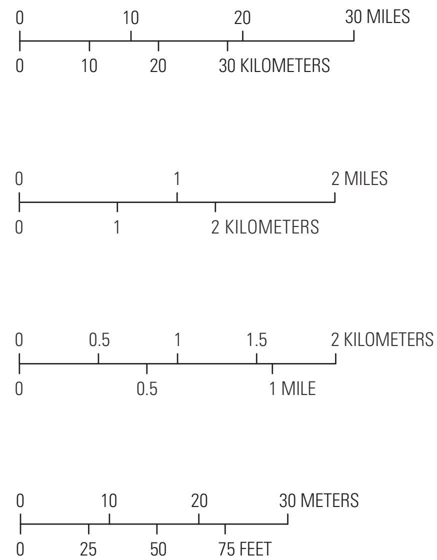
- At a minimum, a location map should show the entire State or all adjoining States that encompass the map area shown in the figure (referred to hereinafter as the "main map") (*A–D*)
- If the main map is large scale (showing a small area), the location map may need to include two parts: a State map showing the location of the county and a county map showing the location of the main map (*B*)
- If the main map is small scale (showing a large area) and is of an easily recognizable area—for example, the entire United States or the western or eastern half of the United States—no location map is needed
- The exact shape of the main map should be shown on the location map; this "map area" will probably be rectangular in shape (*B, C*). An additional area showing "study area" or "model area" may also be shown within the map area (*C, D*)
- All shapes within the location map should be labeled appropriately. If the main map area is a rectangle, show that area on the location map and label it "Map area" (*B, C*). If there is an additional shape within the map area that displays the study area or the model area, label that area "Study area" or "Model area," respectively (*C, D*)
- On the location map, label the State name using Times New Roman Bold, 7 or 8 pt, uppercase. Label the terms "Study area," "Map area," and "Model area," using Univers 57 Condensed, 7 or 8 pt, uppercase and lowercase. The term "Map area" is not needed where the location map and the map area are one and the same (*D*)
- All shapes within the location map may be shown with a stroke and (or) filled with black, gray, or a color, if the fill helps to highlight the location. If the area is small, a dark fill may be used; if the area is large, a light fill may be used. The illustrator should use good judgment in finalizing a useful and accurate location map
- Labeling the location map with the words "Location map" or "Index map" is not recommended
- A location map does not need a base-map credit note, scale bar, coordinate system, or north arrow





Rake Scale

- Required for all page-size maps except location maps
- Requires dual units. Combine English units with corresponding metric units onto one scale, with units used in the report shown on top. The top scale should be the longest
- Should be divided into equal increments of English and metric units, with a minimum of two increments for both sets of units
- Intermediate ticks should not be shown. All ticks should be the same length and should be labeled
- Lineweight is 0.5 pt; a good tick length is 0.05 inch
- Start at zero. No divisions should occur to the left of zero
- Should end with same value, if possible, preferably an even number (for example, 30 miles and 30 kilometers)
- Text is Univers 47 Condensed Light, 7 pt; use commas in numbers greater than 999
- Letters of units of measurement (for example, MILES) should be placed to the right of the largest number on the scale in uppercase
- The length of any scale should be proportional to the size of the map under which it appears. Scale-bar length (not including numbers or units of measurement) should not exceed one-third the width of the map
- Will be centered, preferably, below map, outside the neatline; otherwise, position scale for best fit for figure and for layout



How to Calculate a Rake Scale from Two Lines of Latitude for a Page-Size Map

1. Choose two latitudes shown on a map and measure the distance between them; this assumes the distance is measured along a north-south line and the map is oriented with north on top. Use the information below as a guide to calculate the distance, in kilometers, that is represented. Abbreviations used: lat, latitude; °, degree; ', minute; ", seconds; km, kilometer; cm, centimeter.

If 1° lat=60' lat, and 1° lat=111 km, then 60' lat=111 km

Examples of calculating distance:

$$30' \text{ lat} = \frac{111}{60/30} = \frac{111}{2} = 55.5 \text{ km}$$

$$20' \text{ lat} = \frac{111}{60/20} = \frac{111}{3} = 37 \text{ km}$$

$$15' \text{ lat} = \frac{111}{60/15} = \frac{111}{4} = 27.75 \text{ km}$$

$$10' \text{ lat} = \frac{111}{60/10} = \frac{111}{6} = 18.5 \text{ km}$$

$$7.5' \text{ lat} = \frac{111}{60/7.5} = \frac{111}{8} = 13.875 \text{ km}$$

(Note that 7.5' lat=7'30" lat)

$$5' \text{ lat} = \frac{111}{60/5} = \frac{111}{12} = 9.25 \text{ km}$$

$$1' \text{ lat} = \frac{111}{60/1} = \frac{111}{60} = 1.85 \text{ km}$$

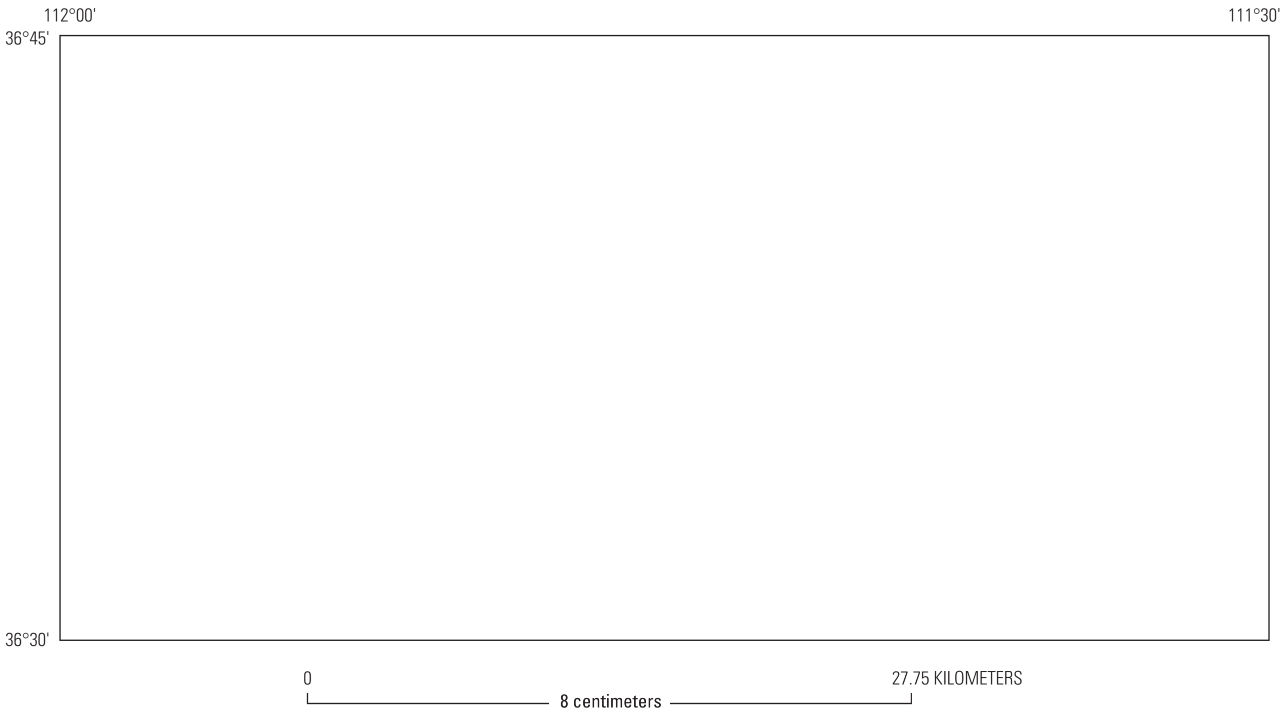
If 1' lat=60" lat, then 0.5' lat=30" lat

$$30'' \text{ lat} = \frac{111}{60/0.5} = \frac{111}{120} = 0.925 \text{ km}$$

2. Using the information gathered, create a rake scale.

Example:

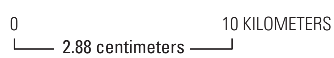
Latitudes labeled on the neatline are 36°30' and 36°45'.
The difference in latitude is 15', and the actual space between the latitudes is 8 cm.
15'=27.75 km=8 cm. In other words, 8 cm on the map is equivalent to 27.75 km.



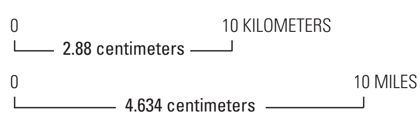
Because rake scales are shown with whole numbers, calculate a proportion to get a correct and basic length for the rake scale, as follows:

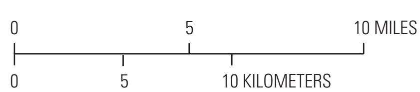
$$\frac{8\text{ cm}}{27.75\text{ km}} = \frac{X\text{ cm}}{10\text{ km}} \qquad X=(8\times10)/27.75=2.88\text{ cm}$$

Therefore, on the rake scale 10 km is represented by a length of 2.88 cm. This gives enough information to build the rake scale to whatever length is appropriate for the width of the map (the scale should not be longer than one-third of the width of the map).



To include miles, multiply 2.88 cm by 1.609. The result—4.634 cm—represents 10 miles on the rake scale.





Placement of Type on Maps [or Illustrations]

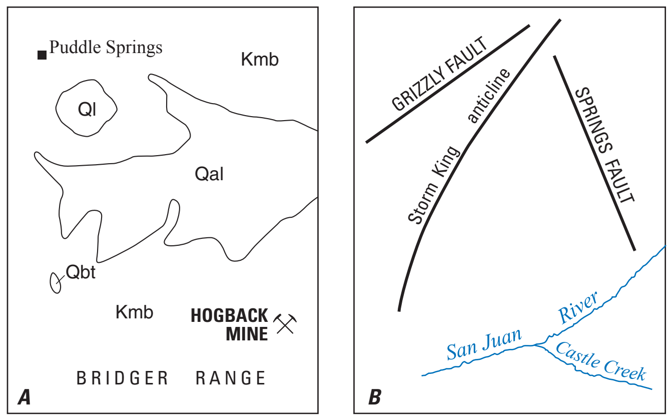
Introduction

This section on type placement is modified from an article by Neil W. Maxfield, titled “Type Placement—Placement of Type on Geologic Maps.” This article was written in 1962 and was released as part of the Branch of Technical Illustrations Instruction Series.

The quality of an illustration can be measured by the uniformity of type placement. Legible type placement makes the illustration useable; uniform type placement makes the useable illustration one of quality.

The placement of type and the positioning of lettering requires care, judgment, planned procedure, a knowledge of map composition, and an understanding of proportion and balance. Each name, and each symbol, must be placed to assure immediate and unmistakable identification of the feature with minimal interference with other map detail.

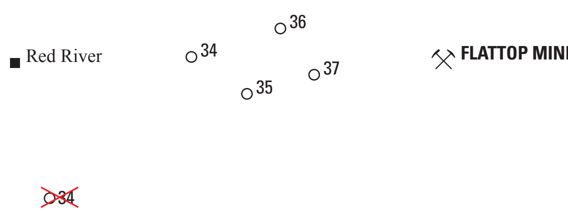
A map is usually read with north at the top; therefore, most names and labels should be positioned parallel to the bottom neatline (see *A* to the right). The exception to horizontal lettering is the labeling of diagonal linear features such as faults, anticlines, streams, and roads. When labeling a diagonal linear feature the type should read from south to north (see *B* to the right) but should not appear to be tipped over backwards. Linear-labeling should be positioned along an imaginary smooth line even when the feature being labeled is extremely crooked.



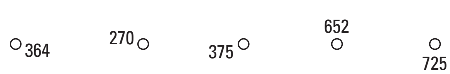
Examples of Type Placement

The legibility of type and symbols is essential to the reader but is not the only consideration. Preferred positioning, correct word spacing, consistent treatment, correct letter spacing, and proper consideration in avoiding type and line overprints are important in the preparation of quality illustrations.

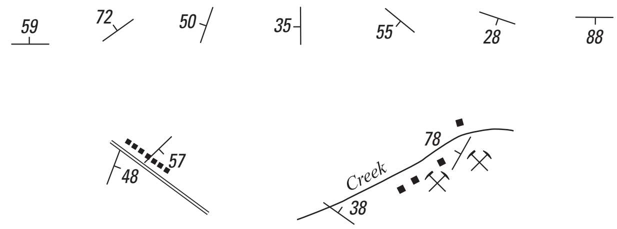
Preferred type placement for labeling small features or symbols is to the upper right. Avoid placing type in alignment with small symbols where the symbol could be read into the lettering.



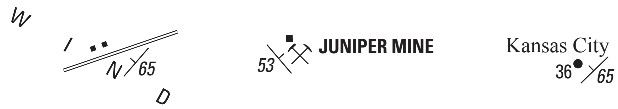
If placement of type in the upper right in impracticable, the other locations that may be used are, in order of preference: lower right, upper left, lower left, centered above, and centered below. These are only alternatives and should not be used if type can be placed in the upper right position without interference with other map detail.



Strike and dip values should be placed so that the dip points to an imaginary dot in the center of the nearest number. Where dips are vertical (or nearly vertical) the entire value should be centered off the dip. Departure from this rule is permitted only when avoiding interference with other map detail. Except for those values that must be moved slightly to improve legibility, there should be a uniform space between dips and their values throughout the illustration.



Placement of a dip value on the back side of the symbol is permitted only when placement on the dip side would interfere with other map detail. If, by placing the value on the dip side, it is too far from the symbol to be easily identified with the symbol, it should be placed on the back side.

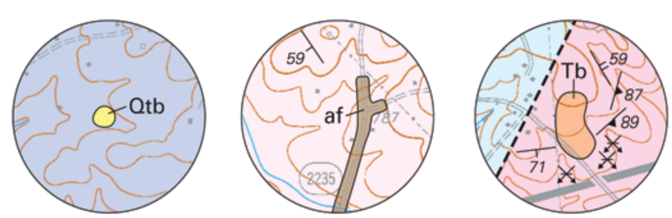


Formation symbols should be placed far enough apart within large units so as not to have duplication within one's immediate range of vision, yet there should be sufficient coverage so that it is not necessary to search for identification of the unit. Fewer formation symbols are needed on multicolor maps than on black and white maps because color will aid the reader in identification of units. Multicolor maps with good color contrast between units will require fewer formation symbols than those with very little color contrast between units. Black and white maps often have several units with patterns to add prominence to certain units. If the map is black and white without any patterned units, it may be necessary to label every area.

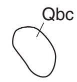
Preferred placement of formation symbols for small areas is centered within the area. Some small, colored areas are easily identified without labeling when the same formation is labeled nearby. If an objectionable overprint of other map detail would result by placing the formation symbol in the center of the area, the symbol should be moved. Do not overprint other type.

If line overprints are necessary to properly identify the area, one should consider the color of the line being overprinted and the lineweight of the line being overprinted. In every case where overprinting a line is necessary, the best solution for type placement will be where there is minimal interference.

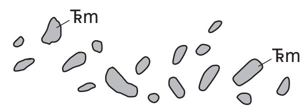
When formation symbols do not fit within the area to be labeled, place the formation symbol outside the area and leader it to the area. Leaders should point from an imaginary dot in the center of the first or last letter of the symbol. Leaders should be of uniform length (0.10 inch) and weight (0.3 pt) throughout the illustration. Leaders should only be placed vertically when it is not possible to leader from an angle. Vertical leaders should point from the center of the entire symbol.



Leaders should cross the contact at nearly right angles. If placed at exactly right angles, it may be confused with a vertical dip; if placed too nearly parallel with the contact, it may not be immediately identifiable as a leader. One third of the leader should be inside the area being labeled, unless a long leader must be used. Long leaders should be avoided but may be necessary, especially on black and white illustrations where so many formation symbols are necessary.



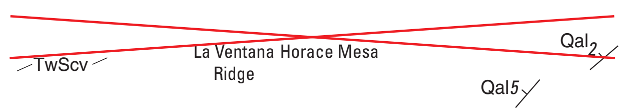
Avoid the use of multiple leaders, especially with multicolor illustrations. Consider the color contrast between the areas being labeled and the surrounding area. If the contrast is easily distinguished, it is not necessary to label each area. If there is little or no contrast between areas, additional formation symbols are preferred to additional leaders unless it would overcrowd the area.



Avoid “back-leadering.” A leader should connect the area with the nearest part of the lettering.

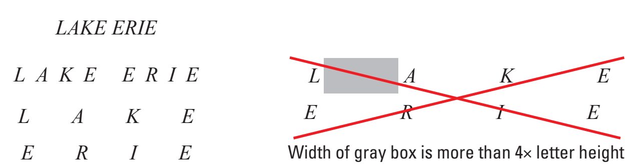
Avoid leadering into a lined pattern in such a way that the leader runs the same direction as the pattern.

Do not place lettering so that it can be read into the label of another feature. Check against other overlays and base type.



Letter Spacing

The spacing between letters should not exceed four times the individual letter height. Use letterspacing if it is desirable to increase the spacing between letters of a ridge or valley name that is too short to properly identify the feature. Names of streams, ridges, valleys, anticlines, synclines, and faults should always be curved to fit the general curved direction of the feature.



Width of gray box is more than 4× letter height

Word Spacing

Spacing between words helps to indicate the extent of the named feature. The components of the feature name should not be placed so far apart that their relation is not immediately evident. For example, on a stream that is not long enough to justify two placements, the tendency is to spread the components widely to suggest the extent of the feature. This practice is justified only when the relation and sequence of the component parts are evident at a glance. On a long feature it is preferable to repeat a name rather than overspread its parts. Where features are of such length that two or more labels are necessary, a larger space should appear between the successive placements than the space provided between the components of one name set. This is particularly applicable to roads, railroads, and streams.

Words in a name are spaced equally unless there is a relation between certain components. Less space should be allowed between related words than between words that are not related.

BIG ROCK   FAULT
Storm King   anticline
Black Bear   Mountain
San Juan   River
North   Fork   Eagle   Creek
North   Fork   Bald Eagle   Creek
San Andres   Limestone
Dewey Lake   Red beds
Central Basin platform
Burro Canyon   Formation
Tiger Mountain   basin
Little Beaver   Ridge

Examples of Word Spacing

The significance of the words must be considered in proper placement of type.

The name of this river is “Big Thompson.”

The name of this river is “Thompson.” This placement of type implies that there are two Thompson Rivers, this one being the larger.

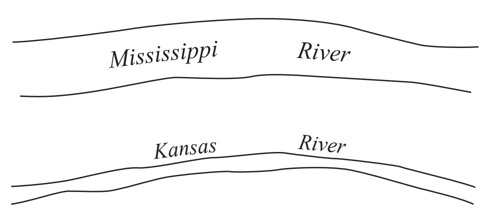
The relation between components should be maintained when it is necessary to place the name on two lines.

Crown Hill
Lake

rather than

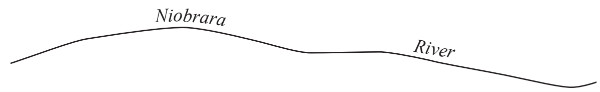
Crown
Hill Lake

The name of a double-line stream is placed within the shoreline of the feature where space permits. Type must be placed entirely within or entirely outside the shoreline of the stream. Type placement above the stream is preferred to type placement below the stream.

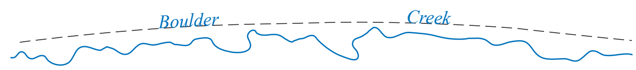


Stream names should be arranged in a smooth line, or curve, above the stream and within the center one-third of the length of the stream.

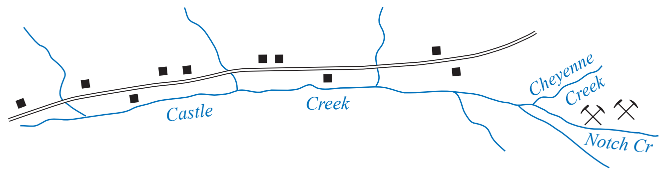
Stream names should be a consistent distance from streams and positioned to avoid compound curves in the type.



If the stream being labeled is extremely crooked, the stream name may follow the general direction of the stream to avoid compound curves. This will also prevent sharp changes in direction of type.

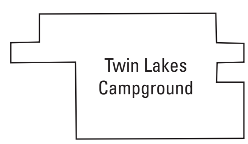


If it is necessary to label on the underside of a stream, all components of the name should be placed on the underside. If it is especially important that a short stream be labeled, it is permissible, as a last resort, to place part of the name above the line and the remaining part below the line. The words “River” and “Creek” may only be abbreviated as a last resort. Do *not* show periods if forced to abbreviate.

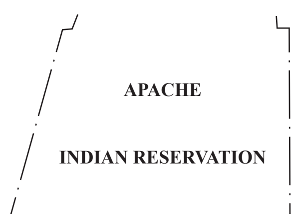


If the area is adequate in size, the lettering is placed within the feature boundaries, preferably centered, and in one line.

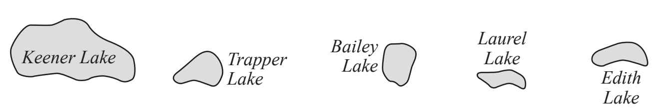
When the name consists of two or more words, the lettering may be placed in two lines, depending upon the length of the name and the size and shape of the area. Lettering should not be shown in three lines unless there is no alternative.



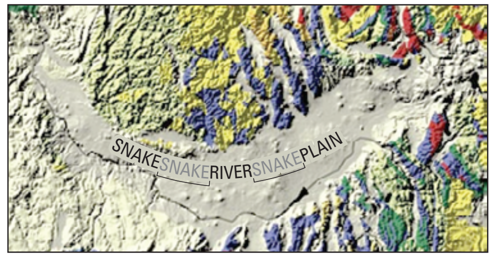
Where area names are placed in two lines, the vertical separation between lines of type should not be greater than (1) one-third of the length of the longer line of type or (2) the length of the shorter line of type, whichever is less.



Names of lakes, reservoirs, ponds, and swamps are arranged horizontally and placed within the limits of the feature if the feature is large enough. If space does not permit placement of type within the limits of the feature, the type may be placed to the right, left, top, or bottom, in that order of preference. When placing two or more lines of type to the side of a feature, align the type vertically on the side next to the feature. When placing two lines of type above or below the feature, center the second line beneath the first line.



Type that identifies an area or a broad feature does not have the immediate visual identification of a linear feature. It does not have a line to help the reader associate between the words and the feature. Therefore it is important that the words are not too widely separated. To assure immediate identification of the complete name of an area, or a broad feature, the space between components of the name should not be greater than the length of the longest word.

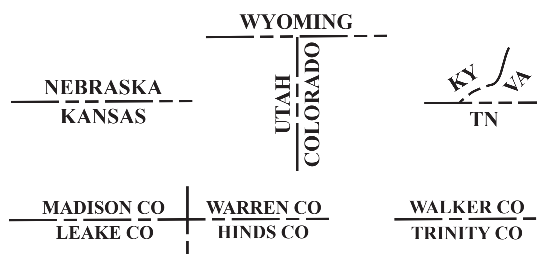


Distance between words should be no wider than the longest word.

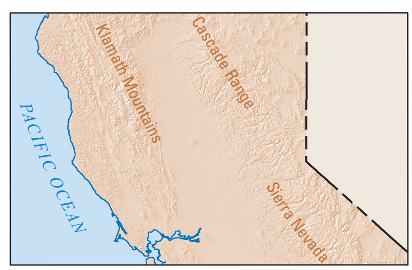
Type that identifies point features—such as schools, peaks, drill holes, and wells—is frequently placed in two lines. The vertical spacing between the two lines of type should normally be about one-half the height of the lettering used.

For simplicity and uniformity, and because it is not good practice to use any mark that could be mistaken for a map symbol, most punctuation marks are omitted from the body of the map. The period is not shown, and the apostrophe is rarely used to indicate possession. Harpers Ferry is the correct map form, not Harper's Ferry. The apostrophe is used only when it is part of the name, such as O'Brien Creek.

When names for States and counties are placed along and parallel to boundary lines, they are centered one over the other wherever practicable. Spell out State names whenever possible. Use postal abbreviations only if necessary.



Names of large cities, civil townships, forests, parks, and reservations are normally placed horizontally and near the center of the feature. Names of small towns, villages, and point features are placed horizontally and, whenever practicable, to the right of the feature. Names of small features—such as mountain peaks, hills, gaps, and passes—should be located to the right of their highest point.



One exception to placing type horizontally is when diagonal features are labeled. The name of a long, narrow mountain or ridge should be placed slightly to the north of the axis of the feature, clear of the top contour lines, and aligned on the general trend of the feature. The names of narrow valleys, canyons, or gorges are placed on the northern side following the general trend of the feature.

Another exception to placing type horizontally is when a map shows a large area with a curved projection (the conterminous United States, for example). Base features, such as State and city names, should be placed relative to the State lines (or graticule): for left third of map, place type tilting to upper left; for middle third of map, place type horizontally; for right third of map, place type tilting to upper right.

Depression Contours

A depression contour is a closed contour (commonly circular or elliptical in shape) inside of which the surface being mapped is at a lower altitude, with respect to the datum, than that outside the contour.

In hydrologic reports, depression contours can be used to show depressions in (1) the upper surface of an aquifer or confining unit, (2) the bedrock surface, or (3) a water surface, such as the water table or potentiometric surface. For a water surface, depression contours can be used effectively to illustrate the cone of depression caused by pumpage from wells.

On topographic maps, depression contours are used to show land surface features. Examples of other types of depressions shown in USGS reports include bathymetric contours (fig. 23), volcanic craters, open pits or quarries, and trenches (refer to FGDC for specifications).

Depression contours are distinguished from other contours on a map by hachures (ticks drawn perpendicular to the contour on the downslope side of the contour). As illustrated (fig. 24), hachures are shown on all depression contours that are closed within the map area; the illustrator has no way of knowing what lies outside of the map boundary.

When more than one depression contour is shown, the space between hachures is least on the depression contour representing the lowest altitude and is greatest on the depression contour representing the highest altitude. When hachures are shown on a map, the explanation should include the statement, “Hachures indicate depression.”

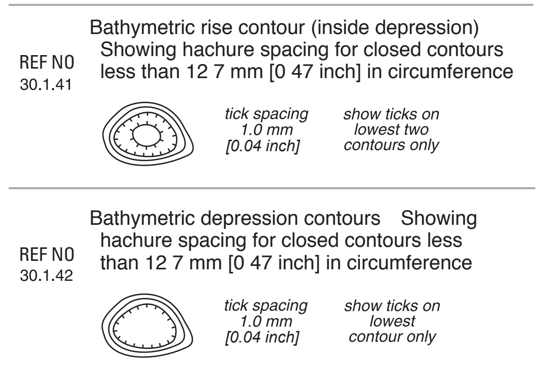


Figure 23. Closed bathymetry contours use hachures. Above are two examples from FGDC showing a rise contour inside a depression and a depression contour. Note that when closed contours are less than 0.47 inch in circumference, ticks should be shown on the lowest contour only. Refer to FGDC (p. A–30–1 to A–30–3) for other examples of depression contours.

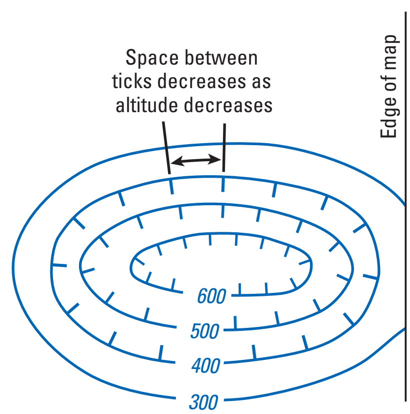


Figure 24. An example of hachures depicting depression contours. Only closed contours have hachures because it is uncertain what happens to the contours beyond the neatline of the map. Note that the space between hachures (shown by ticks) decreases as altitude decreases, thus giving the impression of looking into a depression (or the impression of looking into a depression (or bottomless pit).

A Tip for Creating Hachures

Here is one method for creating hachures. This method decreases the space between the contours as well as the length of the contours. It works for fairly large contours that need more than a dozen ticks. Small contours are best handled by manually creating the ticks. All ticks should be placed perpendicular to the baseline of the contour.

Start with the largest contour (highest altitude). Copy and “Paste in Front” the contour to which you want to add hachures. Put this copy in a new layer and label it “hachures.” Lock the “original contour” layer. Using the “Type on a Path” tool, type several lowercase “L”s. To get the spacing between the hachures that you desire adjust the letter tracking; usually a setting between 500 and 800 is a good fit. Type enough "L"s to complete the contour. Be sure to select Univers 57 Condensed as the font for the “L”s. For index contours, consider using Univers 67 Condensed Bold. The illustrator may have to experiment with point size and letter tracking because both will vary depending on the size of the contour.

Repeat for the adjacent contour. For this contour use a smaller point size for the lowercase “L”; this will reduce the length of the tick and the space between the ticks.

Guidance on Release of Sensitive Water-Related Information

Here is guidance on avoiding the release of sensitive water-related information. Suggested wording for a figure explanation is shown below:

Avoid senstitive wording		Use general wording
Well used for public-water supply	→	Production well
Gwinnett County municipal well	→	Production well
Doug Harvey, test well 1	→	Test well 1
Spring used for public-water supply	→	Spring

The excerpt below from Nathaniel Booth's memorandum of March 13, 2014, has been updated to show USGS punctuation and capitalization styles but not to change the meaning. Emphasis (in bold) has been added. The original memorandum is available at http://nwis.usgs.gov/communications/2014news/140304sensitive_data_guidelines html.

Subject: Guidance on Release of Sensitive Water-Related Information
From: Nathaniel Booth /s/ Nathaniel Booth Chief, Office of Water Information
Date: Thu, Mar 13, 2014 at 2:43 PM

Critical Infrastructure: Water Supply, Wastewater, Energy, and Associated Facilities

USGS employees shall not release precise locational information to any individuals or organizations outside the Federal Government, other than to cooperating State and local agencies, for identified water-supply, wastewater, energy, and associated infrastructure, specifically the latitude and longitude of point locations for public-water-supply intakes, wells, nd springs; associated treatment works and treated-water storage facilities; wastewater-treatment works; thermoelectric and hydroelectric generating facilities; and any facility where there is a reasonable expectation that hazardous materials might be stored or processed. This restriction includes latitude and longitude data obtained from cooperating agencies. The locational data for these sensitive sites will be provided in accordance with the Bureau policy on product access and distribution (http://internal.usgs.gov/gio/eweb/guidelines/product_access html). Precise locational data can be released for some water-supply sites that are not identified as a public supply.

Naming nomenclature for sites in NWIS, sites shown on digital products for display on the Internet, and sites shown in a publicly available report shall not use the terms "public" or "municipal" when referring to specific water intakes, wells, or springs; water or wastewater-treatment works; and finished-water storage facilities. These site names also shall not contain descriptive information that could indicate that the site is owned by or associated with a public agency, such as including the name of the water purveyor or utility agency, or its acronym, in the site name. Likewise, these terms and references shall not be used in public-site descriptions. The term "production well" is acceptable in order to distinguish the site from a monitoring well.

Special attention should be given as appropriate to the naming nomenclature for sites in NWIS, sites shown on digital products for display on the Internet, and sites shown in a publicly available report if the site has any other characteristics that might reasonably be considered sensitive, such as energy production or the storage or processing of hazardous materials. Site names also shall not contain descriptive information that could indicate that a site may be owned by or associated with a sensitive public or private use, such as including the name of the owner, or its acronym, in the site name. Likewise, these terms and references should not be used in public-site descriptions.

Station numbers for newly established sites that meet the criteria for sensitive data should use downstream order numbers or water-use format identifiers when possible, as with surface-water sites and treatment plants and powerplants. The 15-digit identifier format that incorporates latitude and longitude may be used for sites such as wells where the station name, site type, or other characteristic made available to the public does not reveal the sensitive nature of the site, as described above.

The following latitude and longitude data related to public-water-supply and wastewater-treatment infrastructure are not considered sensitive and can be made available to the public: (1) the sampling point for finished (treated) public-water-supply samples collected from the distribution system when the location of the sampling point does not reveal the location of the treatment works and (2) the sampling point for treated wastewater effluent when the location of the sampling point does not reveal the location of the treatment works.

Numbering Systems for Wells, Springs, and Miscellaneous Sites

Introduction

A USGS-assigned identifier needed for recordkeeping is given to each well, spring, or miscellaneous site that is discussed within a USGS report. In addition, State and local identifiers that are alpha-numeric (based on location) or derived from a geographic grid system may be given. Although there are many systems, each State will normally only use one or two of them. Some of the States have changed systems over time, so that one site may have multiple identifiers. Older system numbers are retained because some data records still exist under earlier numbering systems.

In a USGS report, study sites are usually listed in a table within the report. A description of the numbering system is added to a page in the introduction. A description of each system used in the report should be included in this section. (Note: USGS streamgages have a separate identifier system, which is not included on the page describing well and miscellaneous site numbering.) In addition, the author of the report or the area's groundwater specialist can provide more information about the systems and the variations that are currently in use. For these standards, a minimal amount of information is given; this information was extracted from a more comprehensive document compiled by Jacqueline C. Olson (USGS, written commun., February 2010).

Identifier Systems

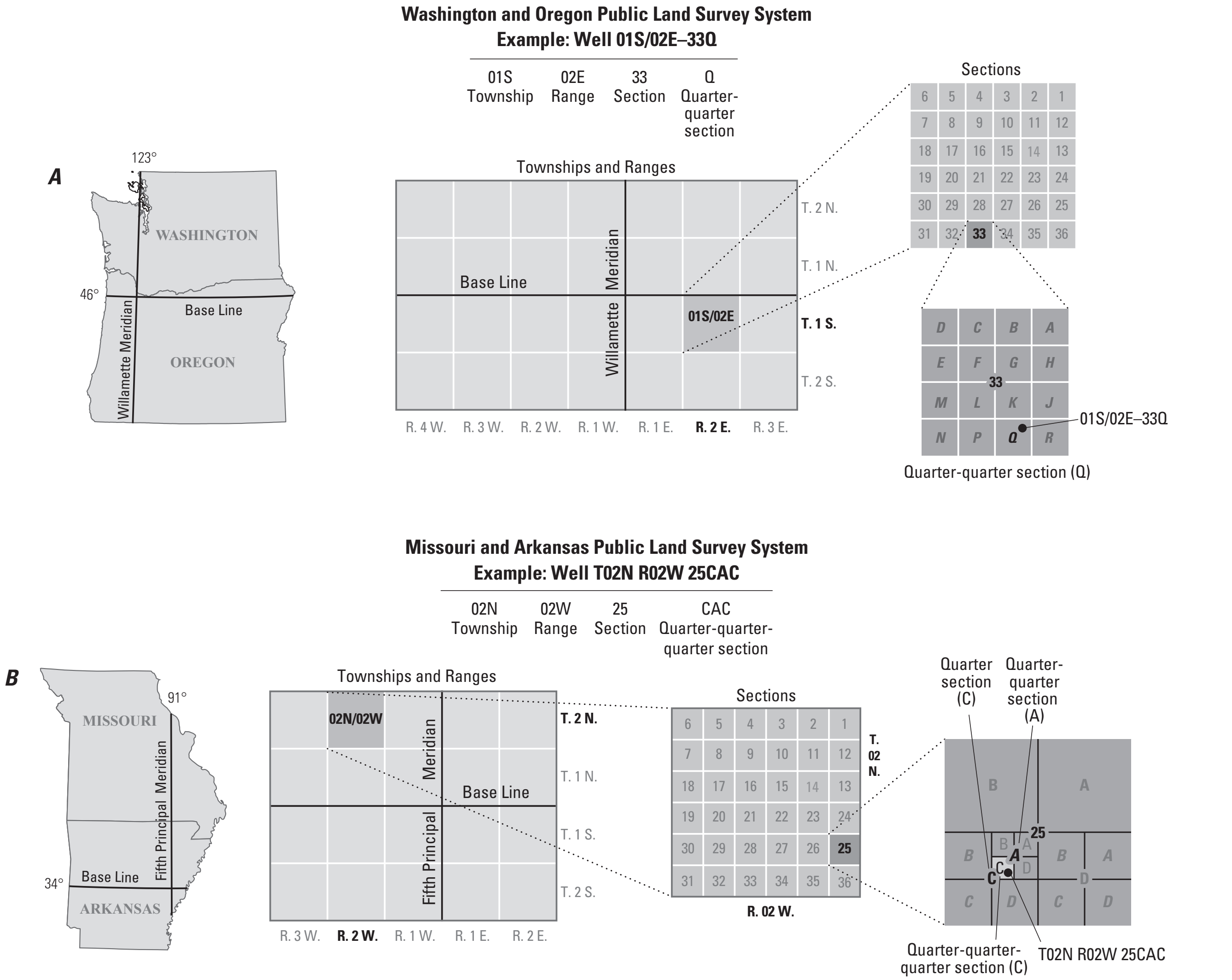
The USGS assigns a number to a well, spring, or miscellaneous site on the basis of its latitude and longitude coordinates; this is the unique number in the National Water Information System (NWIS) and Groundwater Site Inventory (GWSI) databases. This numbering system is used for all groundwater wells and may be applied to offstream and on-stream sites, such as large open-water areas, springs, and water-quality and surface-water miscellaneous sampling sites. Although the number is formed initially from the latitude and longitude of a point believed to represent the location of the site, it is an identifier and not a locator. The number consists of 15 digits: the first 6 digits denote degrees, minutes, and seconds of latitude; the next 7 digits denote degrees, minutes, and seconds of longitude; the last 2 digits are a number unique to that location.

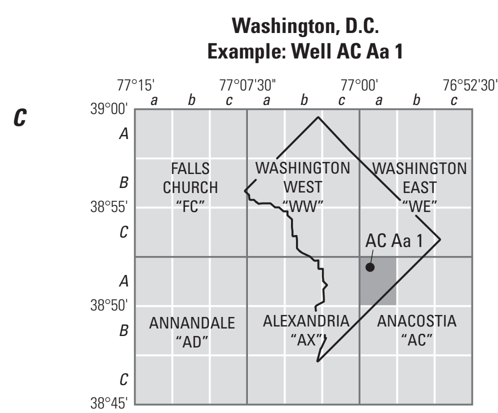
Three general system types are designated at the State, county, or local level:

1. The Public Land Survey System (PLSS), also known as township and range, is used in about one-half of the States. Each State and territory is assigned to a region whose initial survey point is defined as the intersection of a Prime Meridian and a base line (see fig. 22). Each region is subdivided into townships, areas that are approximately 36 square miles, 6 miles on a side. Each township is subdivided into 36 sections, 1 mile on a side. Sections are subdivided into quarter sections, quarter-quarter sections, or irregular governments lots. Within a quarter-quarter section (fig. 25*A*) or a quarter-quarter-quarter section (fig. 25*B*), a unique well number (or letter) is assigned by the State at the time the well is recorded. Where preexisting land parcels were located before the PLSS survey, the sections in these areas will not conform to the standard arrangement, although they will be assigned section numbers.

2. Delaware, Florida, Georgia, Hawaii, Texas, Virginia, and the District of Columbia (fig. 25*C*) use a variation of the latitude-longitude grid.

3. Many States use a local number composed of an abbreviated State, county, town, or parish name plus a sequential number assigned at the time the well is recorded. Identifiers that use a local name-number combination can be described in a sentence in the introduction. Some examples are Mtg-3 (Alabama) and WCW 1135 (Rhode Island—County name abbreviation (WC) plus W (for "well") plus a sequentially assigned number (1135)).





Groundwater studies by the USGS apply a well-numbering system using the five 7½-minute quadrangle maps that cover parts of Washington, D.C. Each quadrangle is divided into nine rectangles by lines drawn at the 2½-minute intervals. The rectangles are lettered *A*, *B*, and *C* from north to south and *a*, *b*, and *c* from west to east. Each quadrangle has an uppercase single or double letter designation. The wells and springs are numbered sequentially in each quadrangle.

Figure 25. Three representative diagrams show some of the numbering systems for wells, springs, and miscellaneous sites that are used throughout the United States. Each diagram has similar features: the hierarchical nature of the systems by linked maps, location of a sample site on the map by its identification number, identification of the components of the number and how each is constructed, and the principal meridians for the Public Land Survey System (PLSS).

The examples for Washington-Oregon and Missouri-Arkansas show two of the PLSS variations. Several States have unique grid systems. The map for Washington, D.C., is an example of a grid designed for a single region or State. Figure modified from Jacqueline C. Olson (USGS, written commun., February 2010).

Visual Variables and Classes of Symbols

Unlike reading—where information is received in a serial fashion (for example, from left to right)—information from a graphic is received all at once and, as such, must make sense to the viewer without too much effort.

A map is a special kind of graphic composed of many interrelated elements. As it is being designed, it must be thought of as a whole. All symbols and colors in the map are affected by their location and appearance relative to other symbols and colors. A change in one symbol may necessitate a change in all symbols (modified from Robinson and others, 1995).

Communicating map information successfully requires that the graphic elements of the map be organized by importance. For example, thematic information is more important than base-map data and should be graphically presented as such.

Visual meaning and importance are assigned to each symbol by the use of primary visual variables, such as size, shape, or hue. A hierarchical organization can be created to show similarities, differences, and interrelations. A visual layering of mapped features can be achieved by using different combinations of the visual variables.

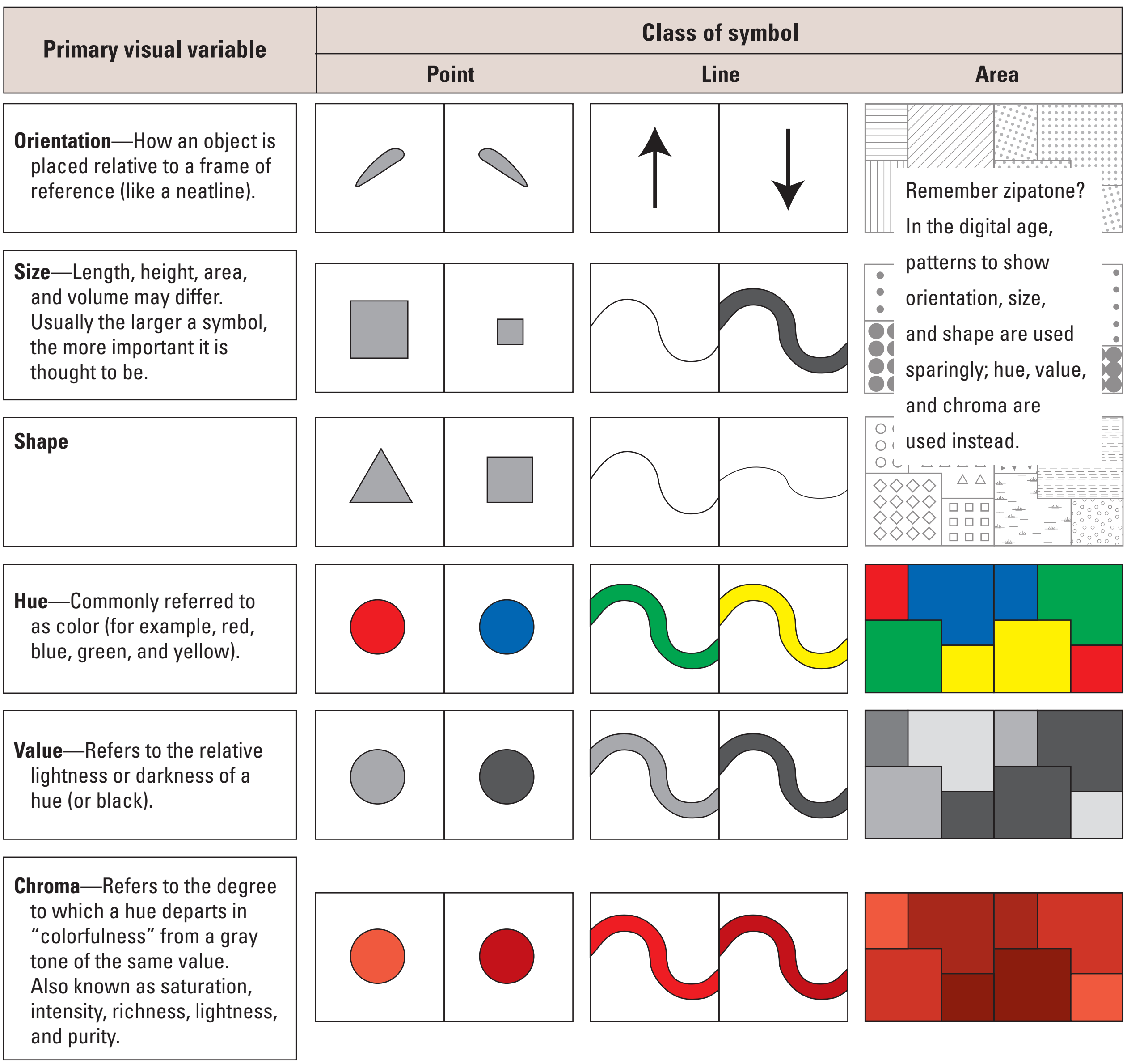


Figure 26. The six primary visual variables as they relate to the three classes of symbols—points, lines, and areas. The visual meaning and importance of points, lines, and areas can be varied by altering one or more of the primary visual variables. Figure modified from Robinson and others (1995).

Classes of Cartographic Symbols

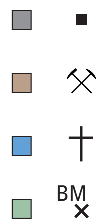
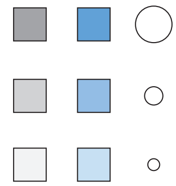
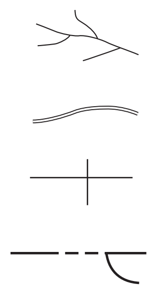
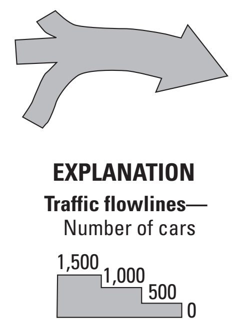
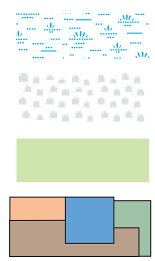
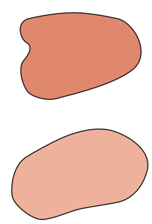
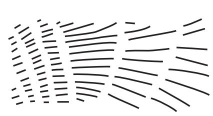
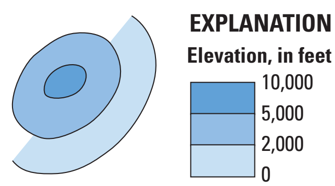
Class of symbol (based on spatial emphasis)	Qualitative distinction	Quantitative distinction (based on rank)
Point—Represents position, location of a feature, intensity at a place, or a representative location for spatial summary data. Examples include well location, water level, and centroid of a distribution.	 Town Mine Church Bench mark	 Large Medium Small
Line—Represents a variety of geographic features. Examples include rivers, roads, and political boundaries. "But use of a line symbol does not always mean that the class of feature being represented is linear. For instance, contours are lines used to represent elevation and depth data, from which volumes may be determined" (Robinson and others, 1995, p. 322).	 River Road Graticule Boundary	
Area—Represents a region with a common attribute. Examples include water features, administrative jurisdictions, or some measureable characteristic. The symbol should be uniform over the entire area.	 Swamp Desert Forest Census regions	 Major industrial region Minor industrial region
Volume—Represents the vertical or intensity dimension of a spatial phenomenon through space. Examples include shaded relief or contours.	 Hachures	

Figure 27. Some examples of the four classes of symbols and how they might be used to display qualitative and quantitative data. In order to add meaning to the symbols, to make them similar or different from one another, or to make them more or less prominent, adjust their appearance by using the visual variables. Figure modified from Robinson and others (1995).

Small-Scale Maps Versus Large-Scale Maps

The concept of small scale and large scale is easily understood when comparing, for example, a neighborhood renewal project to a citywide urban renewal project. The neighborhood renewal project is a small-scale project, and the citywide urban renewal project is a large-scale project.

The concept of small scale and large scale also pertains to maps but is applied quite differently. When referring to small scale versus large scale, what is being compared is the geographic area that is represented on the map. To keep confusion at bay, think of the following phrase:

> "large geographic area equals small scale, and small geographic area equals large scale."

The maps shown in figure 28*A*, *B*, and *C* zero in on selected well sites in the city of Brunswick, Glynn County, Ga. Look at the rake scale accompanying each map. Note that the length of the scale representing 1 kilometer increases from the small-scale map—where 1 kilometer is too small to visualize—to the large-scale map—where 1 kilometer can be easily visualized. Progressing from a small-scale map through a medium-scale map to a large-scale map can be likened to "zooming-in." Zooming-in allows more detail to be shown.

Another way to visualize the concept of small scale versus large scale is to use representational fractions. A representational fraction is defined as a ratio or fraction that relates a distance on a map to a distance on the ground using the same units. For example, on a small-scale map with a scale of 1:1,000,000 (also written as $\frac{1}{1{,}000{,}000}$), one inch on the map represents 1,000,000 inches on the ground. On a large-scale map with a scale of 1:10,000 (also written as $\frac{1}{10{,}000}$), one inch on the map represents 10,000 inches on the ground. Although 1,000,000 is a larger number than 10,000, $\frac{1}{1{,}000{,}000}$ is a smaller number than $\frac{1}{10{,}000}$.

An interesting fact: A map of the world that fits on two 8½" by 11" pages is very small scale, about 1:100,000,000.

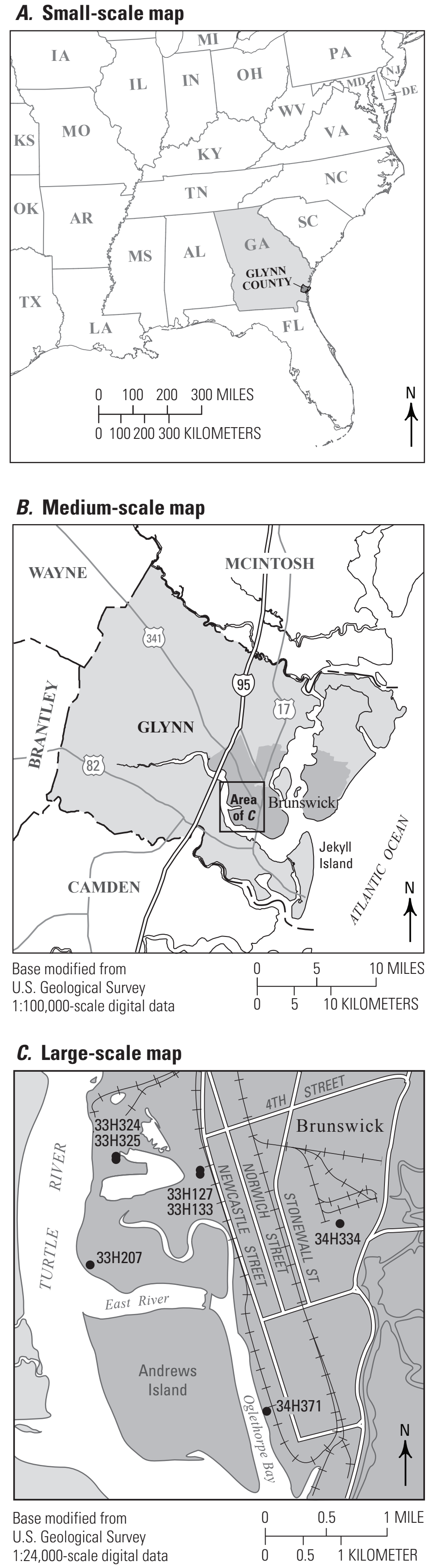


Figure 28. The progression from small scale to large scale. *A*, Small-scale index map showing the State of Georgia; *B*, Medium-scale map showing Glynn County, Ga.; and *C*, Large-scale map showing part of the city of Brunswick, Glynn County, Ga.

Map Projections

Have you ever tried to register two different map layers only to find out that they cannot be registered? Or have you ever tried to mosaic a location map for two adjoining States only to find out that their boundaries do not match? These problems are the result of maps using different projections (fig. 29).

All cartographic products are actually transformations of the almost spherical surface of the Earth (represented by a globe) onto a planar surface (represented by a flat map). These transformations are referred to as map projections. A globe shows area, shape, scale (distance), and direction accurately. Unlike a globe, however, no one map projection can maintain all four of these properties accurately. At best, a particular map projection can accurately portray one of these properties, while distorting the other three.

There are hundreds of different map projections. Some projections are quite old. The Mercator projection, for example, was presented in 1569 by Gerardus Mercator, a Flemish geographer, cartographer, and mathematician. Other projections are not so old. The Robinson projection was presented in 1963 by A.H. Robinson, a geographer, cartographer, and professor. Every projection has its own set of advantages and disadvantages. There is no “best” projection.

One way to classify projections is by the general method used to project the Earth’s surface (globe) onto a plane (flat map). These surfaces (with projection examples) are

- Cylindrical (Mercator (fig. 30), Transverse Mercator, and Universal Transverse Mercator)
- Pseudocylindrical (Robinson, fig. 31)
- Azimuthal (Orthographic and Stereographic)
- Conic (Albers Equal-Area, fig. 32)

Another way to classify projections is by the properties they preserve.

- An equal-area projection preserves area
- A conformal projection preserves shape
- An equidistant projection preserves distance from a standard point
- An azimuthal projection preserves direction from a central point

Map projections commonly used by the USGS are described in Snyder (1987). Also, the USGS maintains a Web site (Map Projections) located at http://egsc.usgs.gov/isb//pubs/MapProjections/projections.html. This Web site provides information on the properties of commonly used projections as an aid to selecting the projection that will best fit a specific need.

Map projection information should be found in the metadata for each coverage. Google Maps™ currently (2015) uses a variant of the Mercator projection for its map images.

Did you know that scientists at the USGS designed the Space Oblique Mercator projection, which allows mapping from satellites with little or no distortion?

Figure 29. Two outlines of Georgia, one from a projection centered on Georgia (black) and one from a projection not centered on Georgia (red).

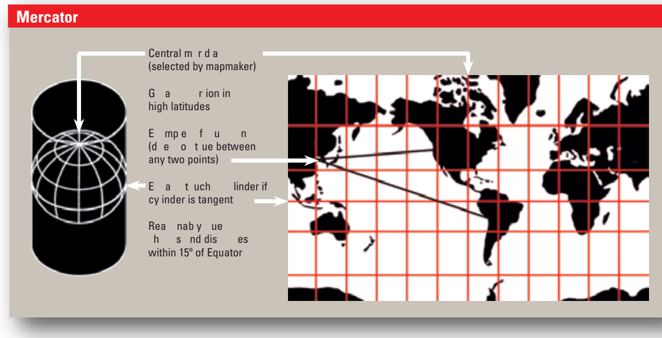


Figure 30. Mercator projection—Used for navigation or for maps of equatorial regions. Mathematically projected on a cylinder tangent to the Equator.

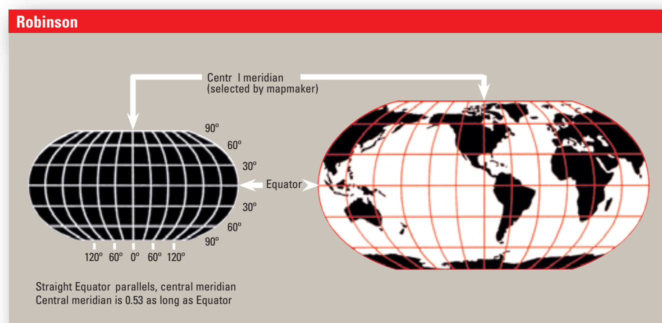


Figure 31. Robinson projection—Uses tabular coordinates rather than mathematical formulas to make the world look “right.” Better balance of size and shape of high-latitude lands than in Mercator. Also called pseudocylindrical or orthophanic (”right-appearing”) projection.

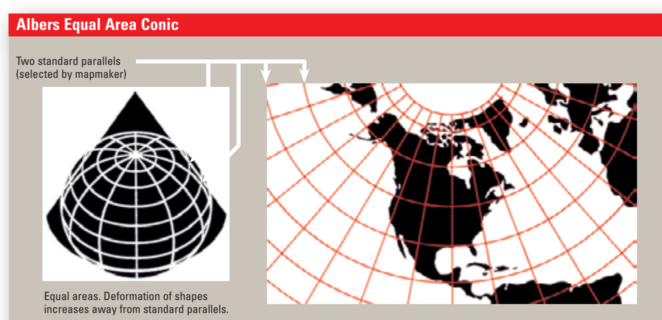


Figure 32. Albers Equal-Area Conic projection—Used by USGS for maps showing the conterminous United States (48 States) or large areas of the United States. Well suited for large countries or other areas that are mainly east-west in extent and that require equal-area representation. Used for many thematic maps. Mathematically projected on a cone conceptually secant at two standard parallels.

Geodetic Datums

The concept of datums can be difficult to grasp. A datum defines the starting point from which coordinates are measured. Latitude and longitude coordinates, for example, are determined by their distance from the Equator and the Prime Meridian that passes through the Royal Observatory, Greenwich, United Kingdom. But where *exactly* is the Equator? And where *exactly* is the Prime Meridian? And how does the irregular shape of the Earth figure into our measurements? All of these issues are defined by the datum (http://education.usgs.gov/lessons/coordinatesystems.pdf).

A geodetic datum is an abstract coordinate system with a reference surface (such as sea level) that serves to provide known locations to begin surveys and create maps. In this way, datums act similar to starting points when you give someone directions. For instance, when you want to tell someone how to get to your house, you give them a starting point that they know, like a crossroads or a building address. Datums are used to create starting or reference points for floodplain maps, property boundaries, construction surveys, levee design, or other work requiring accurate coordinates that are consistent with one another (http://oceanservice noaa.gov/facts/datum html). The National Geodetic Survey (http://www ngs.noaa.gov/) is responsible for defining the official geodetic datums for the United States.

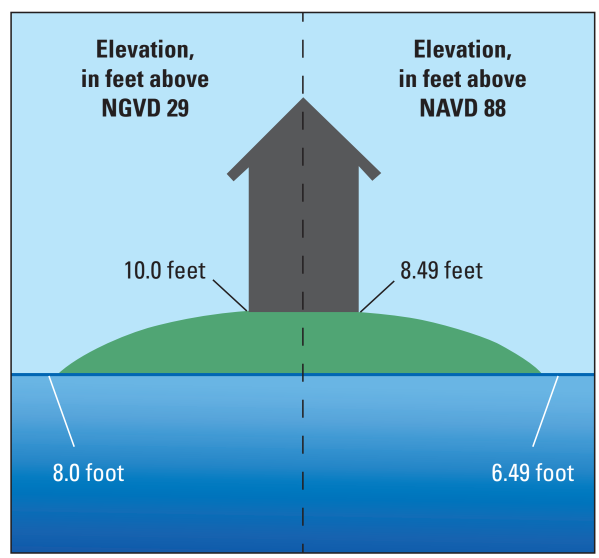
Benchmark information used in the creation of geodetic datums.

Vertical Datums

A vertical datum is a surface of zero elevation to which heights of various points are referred in order that those heights be in a consistent system. More broadly, a vertical datum is the entire system of the zero elevation surface and methods of determining heights relative to that surface (http://www.ngs.noaa.gov/datums/vertical/; http://www ngs noaa.gov/faq.shtml). In USGS reports, vertical datums are used to determine elevations of land surface and bathymetry, and altitude of a water table or potentiometric surface. A datum statement should be included in the explanation for maps (see p. 29). A datum statement is also required for cross sections (see p. 94).

Vertical datums typically used in USGS reports are as follows:

1. National Geodetic Vertical Datum of 1929 (NGVD 29). The Sea Level Datum of 1929 was the vertical control datum established in the United States by the General Adjustment of 1929. Mean sea level was measured at 26 tide gages: 21 in the United States and 5 in Canada. Because the Sea Level Datum of 1929 was not a pure model of mean sea level, the geoid, or any other equipotential surface, it was renamed NGVD 29 in 1973.
2. North American Vertical Datum of 1988 (NAVD 88) was established in 1991 by the minimum-constraint adjustment of geodetic leveling observations in Canada, the United States, and Mexico. It held fixed the height of the primary tidal benchmark, referenced to the International Great Lakes Datum of 1985 local mean sea level height value, at Rimouski, Quebec, Canada. *NAVD 88 didn't replace NGVD 29, it's just a more accurate datum*.



Elevation values based on different vertical datums cannot be used together directly because they are based on different vertical reference points. Failure to take into account these differences could result in a flooded basement. Modified from http://www.region2coastal.com/view-flood-maps-data/understanding-vertical-datums/.

The overall difference for the conterminous United States between heights referred to NGVD 29 and NAVD 88 ranges from –40 centimeters (–1.3 feet) to +150 centimeters (+4.9 feet) (http://www.ngs noaa.gov/PUBS_LIB/NAVD88/navd88report htm). Although the difference is minimal, if you are talking about flood inundation, that amount of error could be problematic.

3. Sea level is used only for references to very general elevations. Mean sea level (MSL) is a tidal datum that pertains to local mean sea level at the tide station at which it was observed and s*hould not be confused with or substituted for* the fixed datums of NGVD 29 or NAVD 88.

Near coastal areas, mean sea level and other tidal datums are determined by analyzing observations from a tide gage. This image shows a tide gage at the St. Charles Parish Water Level Monitoring System in Louisiana (http://oceanservice.noaa.gov/facts/datum.html).

Horizontal Datums

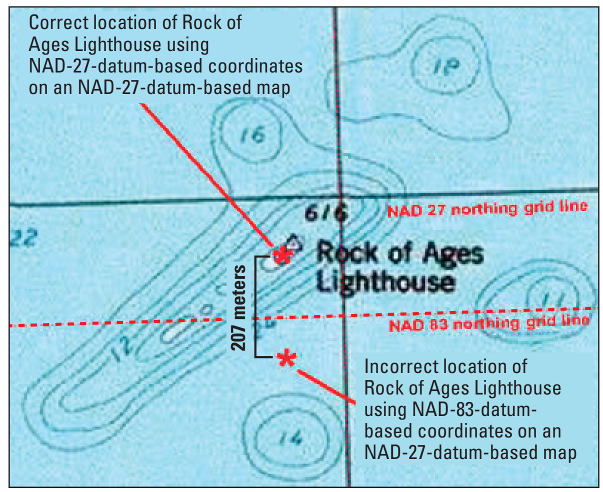
Horizontal datums are used to determine positions, in a coordinate system such as latitude and longitude, on the Earth's surface (http://oceanservice.noaa.gov/education/kits/geodesy/geo05_horizdatum html; http://www ngs noaa.gov/faq.shtml#HorzDiff). In USGS reports, horizontal datums are used to locate wells and streamgages.

Horizontal datums typically used in USGS reports are as follows:

1. North American Datum of 1927 (NAD 27) uses a starting point at a base station in Meades Ranch, Kansas, and the Clarke Ellipsoid to calculate the shape of the Earth. Most USGS topographic maps were published using NAD 27, and many projects by the U.S. Army Corps of Engineers and other agencies were defined in NAD 27, *so the datum remains important despite more refined datums being available*.

2. North American Datum of 1983 (NAD 83) was developed thanks to the advent of satellites and an improved ellipsoid model (Geodetic Reference System 1980). Depending on one's location, coordinates obtained using NAD 83 could be *hundreds of meters* away from coordinates obtained using NAD 27 (http://education.usgs.gov/lessons/coordinatesystems.pdf).

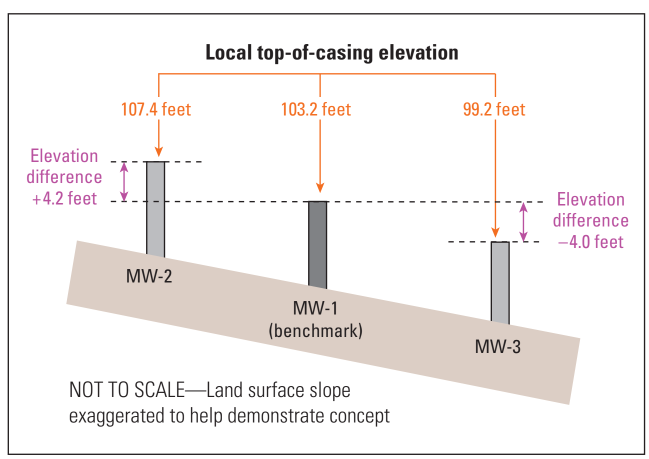
3. World Geodetic System of 1984 (WGS 84) is identical to NAD 83 for most practical purposes within the United States. The differences are only important when an extremely high degree of precision is needed. WGS 84 is the default datum setting for almost all global positioning system (GPS) devices. But most USGS topographic maps published up to 2009 use NAD 27. This conflict in datums can cause big problems for the uninformed GPS user.



A 207-meter northing error is the result of using NAD-83-datum-based coordinates for the Rock of Ages Lighthouse on an NAD-27-datum-based quadrangle. Modified from http://therucksack.tripod.com/MiBSAR/LandNav/Datums/MapDatums.htm.

Local Datums

A local datum also may be used in USGS reports. In the example to the right, the middle well (MW-1) on the site is assigned an arbitrary elevation (benchmark) of 103.2 feet, and the other wells on the site are surveyed relative to that "benchmark."



Examples of Maps

Small-Scale Maps Used in Circulars and Fact Sheets

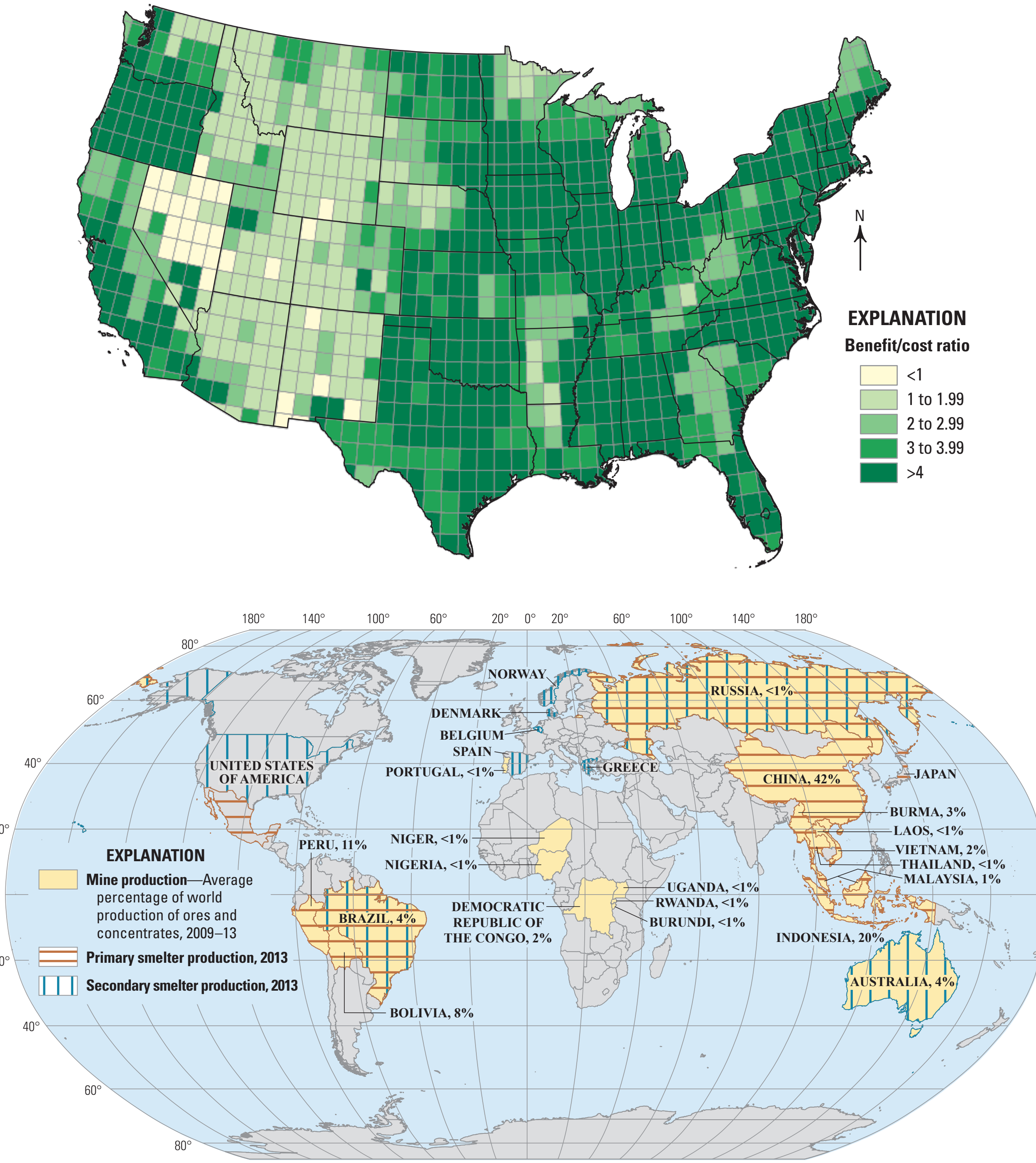
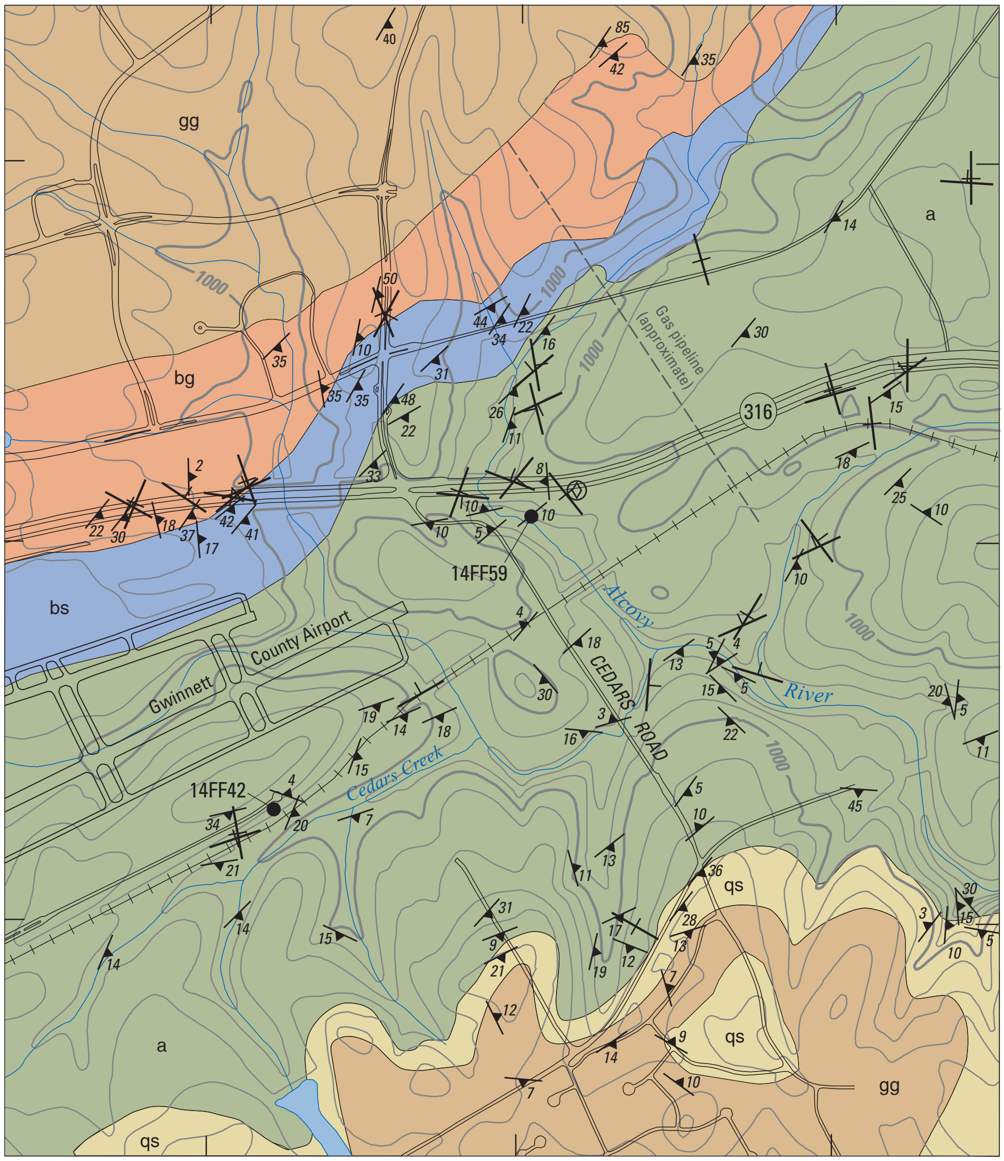


Figure 33. For maps intended for the general public, such as those used in circulars and fact sheets, the standards are more flexible. In the map of the conterminous United States, neither a coordinate system nor a rake scale is shown. The map is more like a diagram showing the overall trend of the data. The map of the world shows the coordinate system but no rake scale. Neither map has a base-map credit note.

Top, Variations in the benefit/cost ratio for the recommended program that would acquire uniform quality level 2 elevation data for the conterminous United States. The darker shades represent the higher benefits. Figure modified from Sugarbaker and others (2014). Bottom, Global producers of tin industrial products in 2013 and percentage of 2009–13 average world tin mine production by country. Figure from Bermúdez-Lugo (2014).

Map with Contours



Base from U.S. Geological Survey digital data
Lawrenceville, 1998, 1:24,000

0 1,000 2,000 FEET
0 250 500 METERS

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Figure 34. Topographic contours shown as part of the base map. Topographic contour numbers never have commas; this is the only exception to the "use commas in numbers greater than 999" rule. The contour interval and the vertical datum note should be shown beneath the rake scale. A contour interval should not be shown without a datum note.

Geologic map and well locations, Gwinnett County Airport area, Georgia. Figure modified from Williams and others (2005).

EXPLANATION

Lithologic unit

- gg — Granite gneiss
- bg — Biotite gneiss
- bs — Button schist
- a — Amphibolite
- qs — Quartzite and aluminous schist

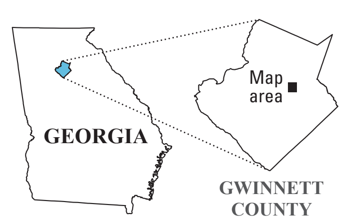
14FF42 ● **Well and identifier**

Joint

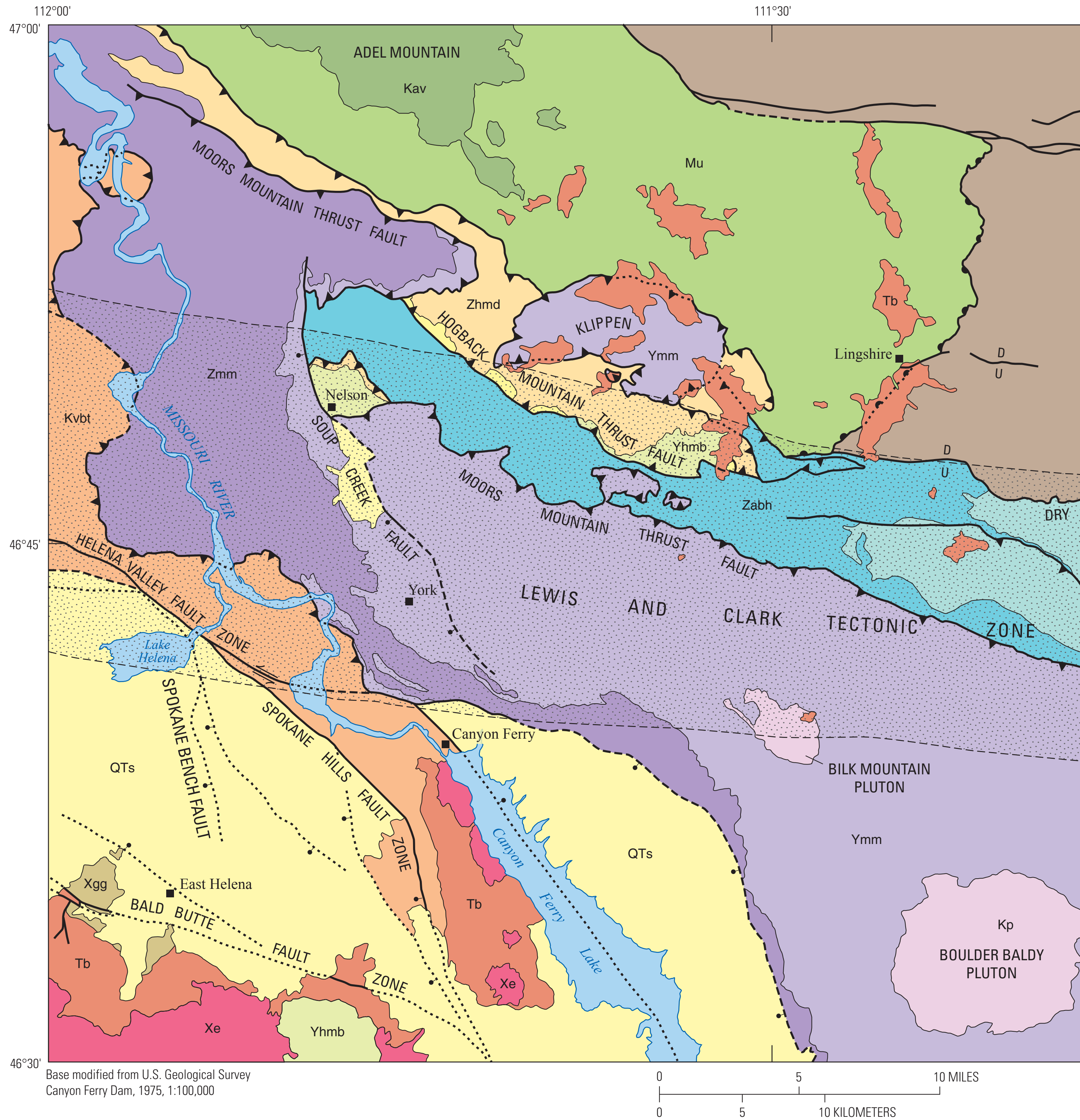
- Inclined—Showing strike and dip direction
- Vertical

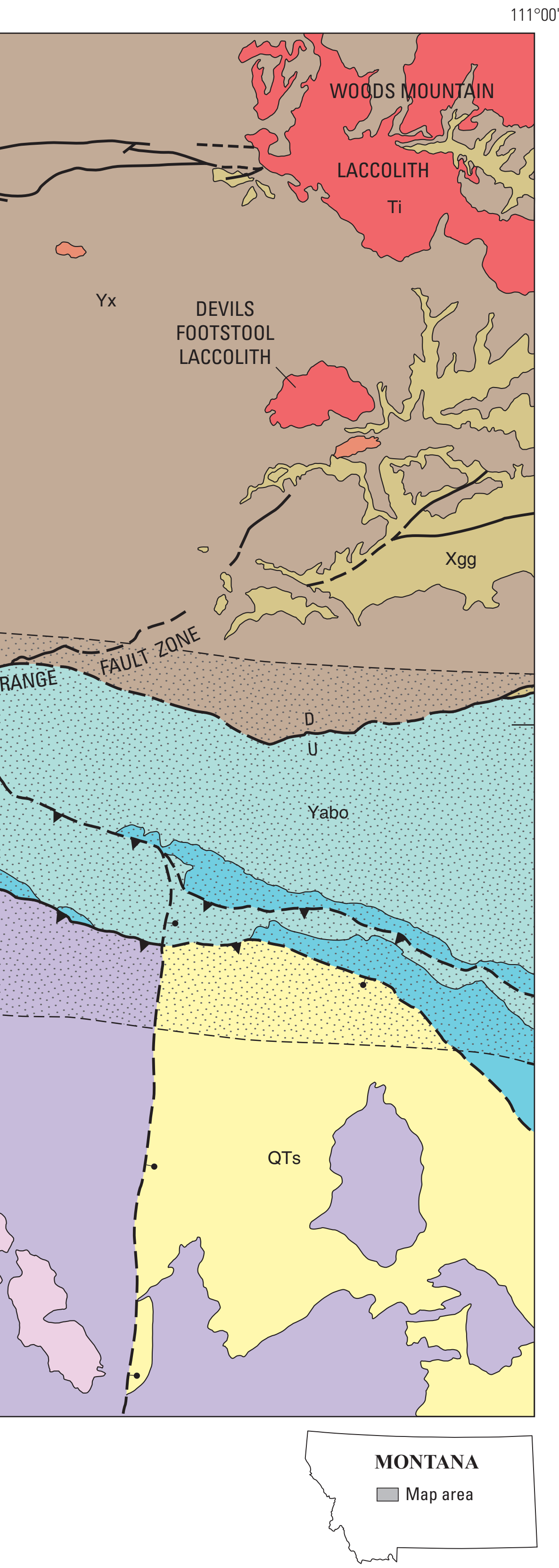
Foliation

- 7 Inclined—Showing strike and dip
- Horizontal



Map Placed Across a Gutter





EXPLANATION

[Some Quaternary and Tertiary deposits are not shown]

QTs **Sediments and sedimentary rocks (Quaternary and Tertiary)**—Occur in valleys resulting from basin and range extension

Tb **Basalt flows (Oligocene)**

Ti **Intrusive rocks in laccoliths (Eocene)**

Kav **Adel Mountain Volcanics (Cretaceous)**

Kp **Plutonic rocks (Cretaceous)**—Penetrate the Moors Mountain thrust sheet

Kvbt **Volcanic breccia and tuff (Cretaceous)**

Mu **Frontal fold and fault belt rocks, undivided (Upper Mississippian)**

Moors Mountain thrust sheet

Zmm Crystalline rocks (Neoproterozoic)

Ymm Crystalline rocks (Mesoproterozoic)

Hogback Mountain thrust sheet

Zhmd Dacite (Neoproterozoic)

Yhmb Biotite granodiorite (Mesoproterozoic)

Avalanche Butte structural block

Zabh Hornblende diorite (Neoproterozoic)

Yabo Olivine gabbro (Mesoproterozoic)

Xe Igneous rocks (Paleoproterozoic)—Penetrate the Eldorado thrust sheet and thrust sheets to the west and southwest

Autochthon

Yx Crystalline rocks (Mesoproterozoic)

Xgg Granite gneiss (Paleoproterozoic)

Contact—Dotted where concealed by water

Fault—Dashed where inferred; dotted where concealed by Cenozoic units or water

Fault of undetermined type

Edge of décollement surface at base of frontal fold and fault belt

High-angle normal fault—Bar and ball on downthrown block

D
U
High-angle reverse fault—U, upthrown block; D, downthrown block

Strike-slip fault—Arrows show relative movement

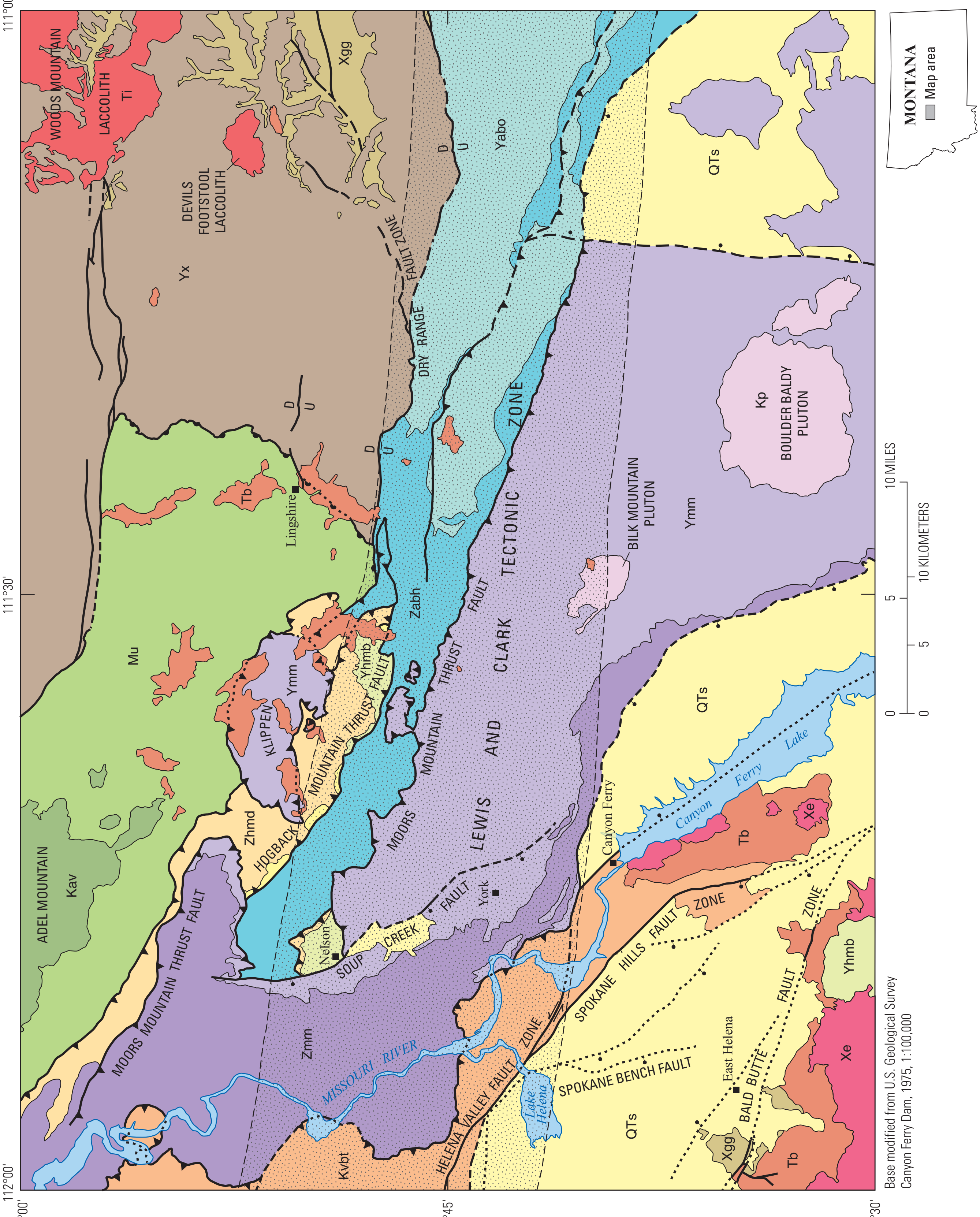
Thrust fault—Sawteeth on upper plate

Inferred approximate boundary of the Lewis and Clark tectonic zone

Figure 35 (pages 78 and 79). A page-size geologic map that extends across the gutter with accompanying explanation and figure caption. If the possibility exists that map data might be lost in the gutter, consider the following. A second option would be to reduce the map so that it could fit on one page. The explanation would be placed below the map (in two columns), and the figure caption would be placed below the explanation. Reducing a map of this complexity so it, the explanation, and the figure caption all fit on one page might not serve the reader well in that type, symbology, and small polygons could become unreadable. A third option would be to rotate the map 90° and show it as a sidetitle illustration (landscape orientation; see figure 36 on pages 80–81).

Tectonic map of the Canyon Ferry Dam 30' x 60' quadrangle, west-central Montana. Figure modified from Reynolds and Brandt (2005).

Landscape Maps and Explanations Across a Two-Page Spread



EXPLANATION

[Some Quaternary and Tertiary deposits are not shown]

QTs **Sediments and sedimentary rocks (Quaternary and Tertiary)**—Occur in valleys resulting from basin and range extension

Tb **Basalt flows (Oligocene)**

Ti **Intrusive rocks in laccoliths (Eocene)**

Kav **Adel Mountain Volcanics (Cretaceous)**

Kp **Plutonic rocks (Cretaceous)**—Penetrate the Moors Mountain thrust sheet

Kvbt **Volcanic breccia and tuff (Cretaceous)**

Mu **Frontal fold and fault belt rocks, undivided (Upper Mississippian)**

Moors Mountain thrust sheet

Zmm Crystalline rocks (Neoproterozoic)

Ymm Crystalline rocks (Mesoproterozoic)

Hogback Mountain thrust sheet

Zhmd Dacite (Neoproterozoic)

Yhmb Biotite granodiorite (Mesoproterozoic)

Avalanche Butte structural block

Zabh Hornblende diorite (Neoproterozoic)

Yabo Olivine gabbro (Mesoproterozoic)

Xe Igneous rocks (Paleoproterozoic)—Penetrate the Eldorado thrust sheet and thrust sheets to the west and southwest

Autochthon

Yx Crystalline rocks (Mesoproterozoic)

Xgg Granite gneiss (Paleoproterozoic)

Contact—Dotted where concealed by water

Fault—Dashed where inferred; dotted where concealed by Cenozoic units or water

Fault of undetermined type

Edge of décollement surface at base of frontal fold and fault belt

High-angle normal fault—Bar and ball on downthrown block

D
U
High-angle reverse fault—U, upthrown block; D, downthrown block

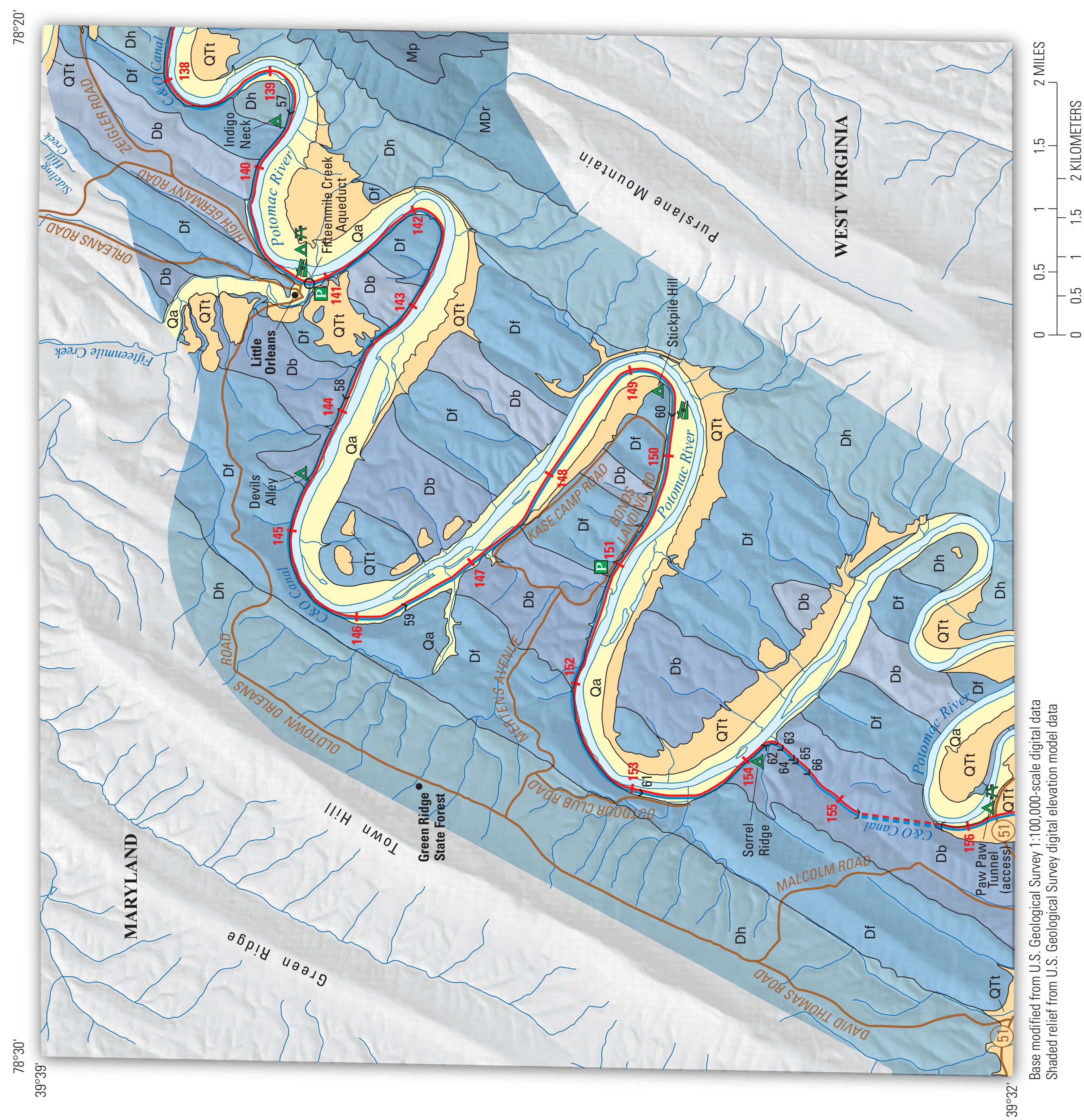
Strike-slip fault—Arrows show relative movement

Thrust fault—Sawteeth on upper plate

Inferred approximate boundary of the Lewis and Clark tectonic zone

Figure 36 (pages 80 and 81). A page-size geologic map rotated 90° and shown as a sidetitle figure (landscape orientation) with accompanying explanation and figure caption. The term "explanation" is centered over both columns of text. See figure 35 on pages 78–79 for an alternate way of presenting this illustration.

Tectonic map of the Canyon Ferry Dam 30' x 60' quadrangle, west-central Montana. Figure modified from Reynolds and Brandt (2005).



Base modified from U.S. Geological Survey 1:100,000-scale digital data
Shaded relief from U.S. Geological Survey digital elevation model data

EXPLANATION

Qa	**Alluvium (Holocene)**—Unconsolidated clay, silt, and gravel
QTt	**Terrace deposits (Holocene, Pleistocene, and Tertiary?)**—Sand, gravel, and boulders
Mp	**Purslane Formation (Lower Mississippian)**—Sandstone
MDr	**Rockwell Formation (Lower Mississippian and Upper Devonian)**—Sandstone, siltstone, and shale
Dh	**Hampshire Formation (Upper Devonian)**—Sandstone, siltstone, and shale
Df	**Foreknobs Formation (Upper Devonian)**—Sandstone, siltstone, and shale
Db	**Brallier Shale (Upper Devonian)**
	Contact
•	**Point of interest**
	Chesapeake and Ohio Canal
	Towpath
— 153	Mile marker—From Washington, D.C., to Cumberland, Md.
P	Access—Parking, boat launch, campsite, picnic area
57	Lock
) (	Paw Paw Tunnel
O	Aqueduct

Lock 60 was lined with wood in order to help water seal the rough-cut sandstone, which was locally quarried from Devonian rock.

Figure 37 (pages 82 and 83). A page-size geologic map with a shaded-relief base, explanation, photograph, and figure caption, all rotated 90° and shown as a sidetitle figure (landscape orientation). This map is one in a series of maps in the appendix of a USGS professional paper. One index map showing the location of all the quadrangles in this series is shown at the beginning of the appendix; therefore, each individual map does not require its own location map. The colors on the map (except the Quaternary units) are screened by using 70 percent transparency with the multiply mode. The shaded-relief base map is screened by using 30 percent transparency with the normal mode to allow the map-unit colors to "pop." Because the screened colors on the map are overlaying the gray shaded-relief base, some of the blues do not quite match their equivalents in the explanation. See, for example, the northwesternmost polygon of "Dh." Because the polygon is labeled "Dh," the reader knows that it is the Hampshire Formation. Without the label, a reader might not be entirely sure that this particular polygon is, in fact, the Hampshire Formation. A way to make the colors in the figure more closely match those in the explanation is to add a touch of gray to all colors (except the Quaternary units) in the explanation boxes so as to mimic what is shown in the figure.

Geologic map of the Chesapeake and Ohio Canal National Historical Park and Potomac River Corridor from mile marker 138 to Paw Paw Tunnel (mile marker 156). Figure modified from Southworth and others (2008).

Portrait Map and Explanation on a Two-Page Spread

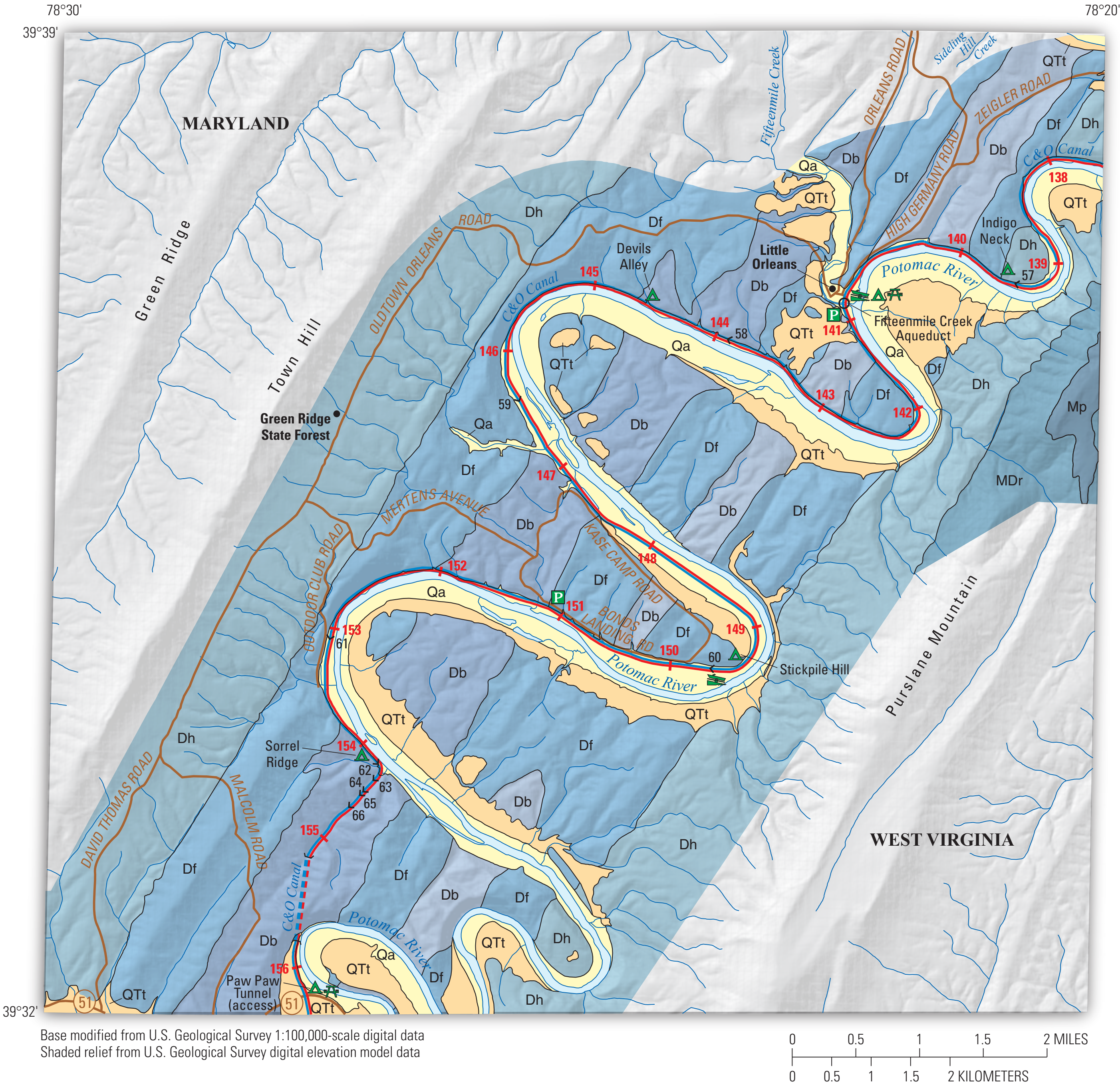


Figure 38 (pages 84 and 85). A page-size geologic map with a shaded-relief base, explanation, photograph, and figure caption shown on a two-page spread (portrait orientation). This figure is the same as that shown on pages 82 and 83. Those pages show the layout as it appears in the original publication, the figure being 1 of 19 that were laid out as sidetitle illustrations. As a stand-alone figure, however, it can be shown as above.

Geologic map of the Chesapeake and Ohio Canal National Historical Park and Potomac River Corridor from mile marker 138 to Paw Paw Tunnel (mile marker 156). Figure modified from Southworth and others (2008).

EXPLANATION

Qa	**Alluvium (Holocene)**—Unconsolidated clay, silt, and gravel
QTt	**Terrace deposits (Holocene, Pleistocene, and Tertiary?)**—Sand, gravel, and boulders
Mp	**Purslane Formation (Lower Mississippian)**—Sandstone
MDr	**Rockwell Formation (Lower Mississippian and Upper Devonian)**—Sandstone, siltstone, and shale
Dh	**Hampshire Formation (Upper Devonian)**—Sandstone, siltstone, and shale
Df	**Foreknobs Formation (Upper Devonian)**—Sandstone, siltstone, and shale
Db	**Brallier Shale (Upper Devonian)**
	Contact
	Point of interest
	Chesapeake and Ohio Canal
	Towpath
153	Mile marker—From Washington, D.C., to Cumberland, Md.
	Access—Parking, boat launch, campsite, picnic area
57	Lock
	Paw Paw Tunnel
	Aqueduct

Lock 60 was lined with wood in order to help water seal the rough-cut sandstone, which was locally quarried from Devonian rock.

Maps Using White Type or White-Outline Type

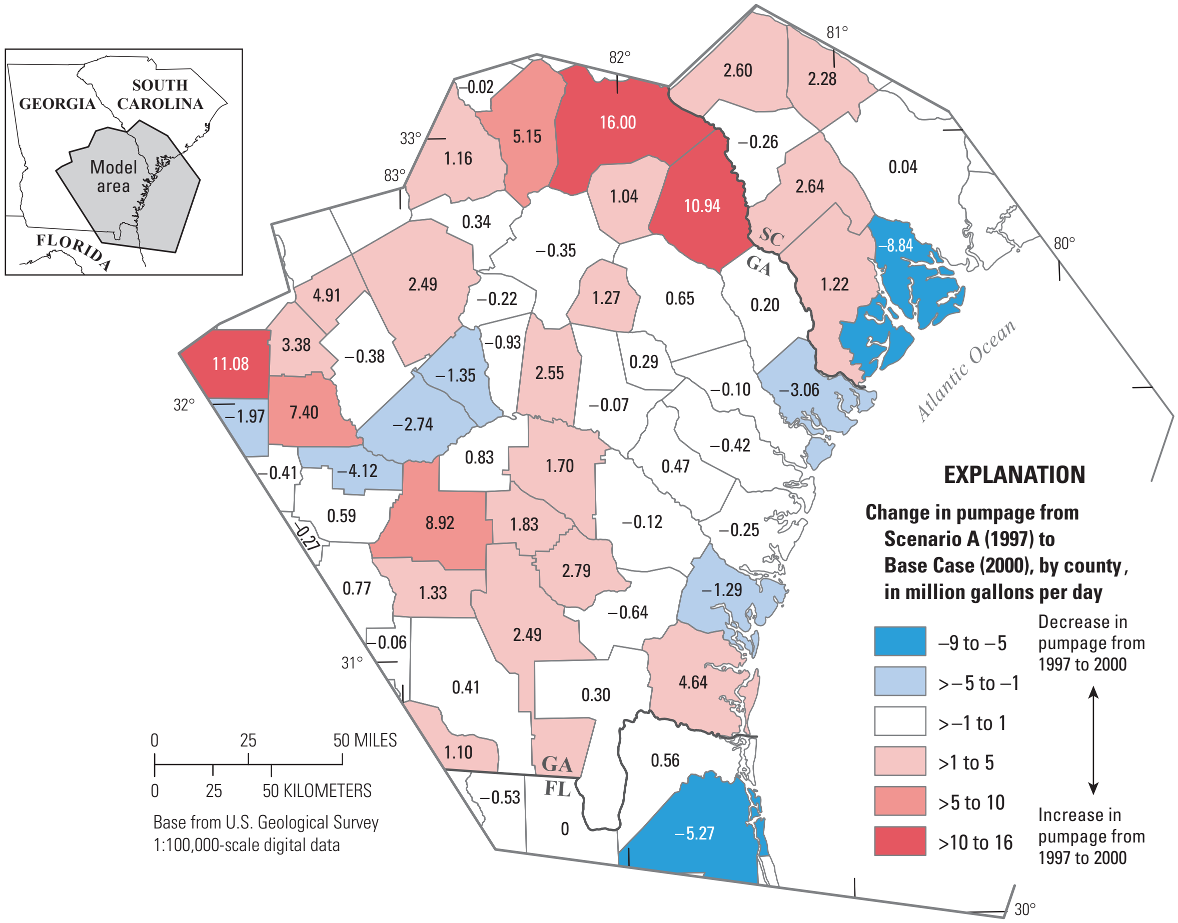
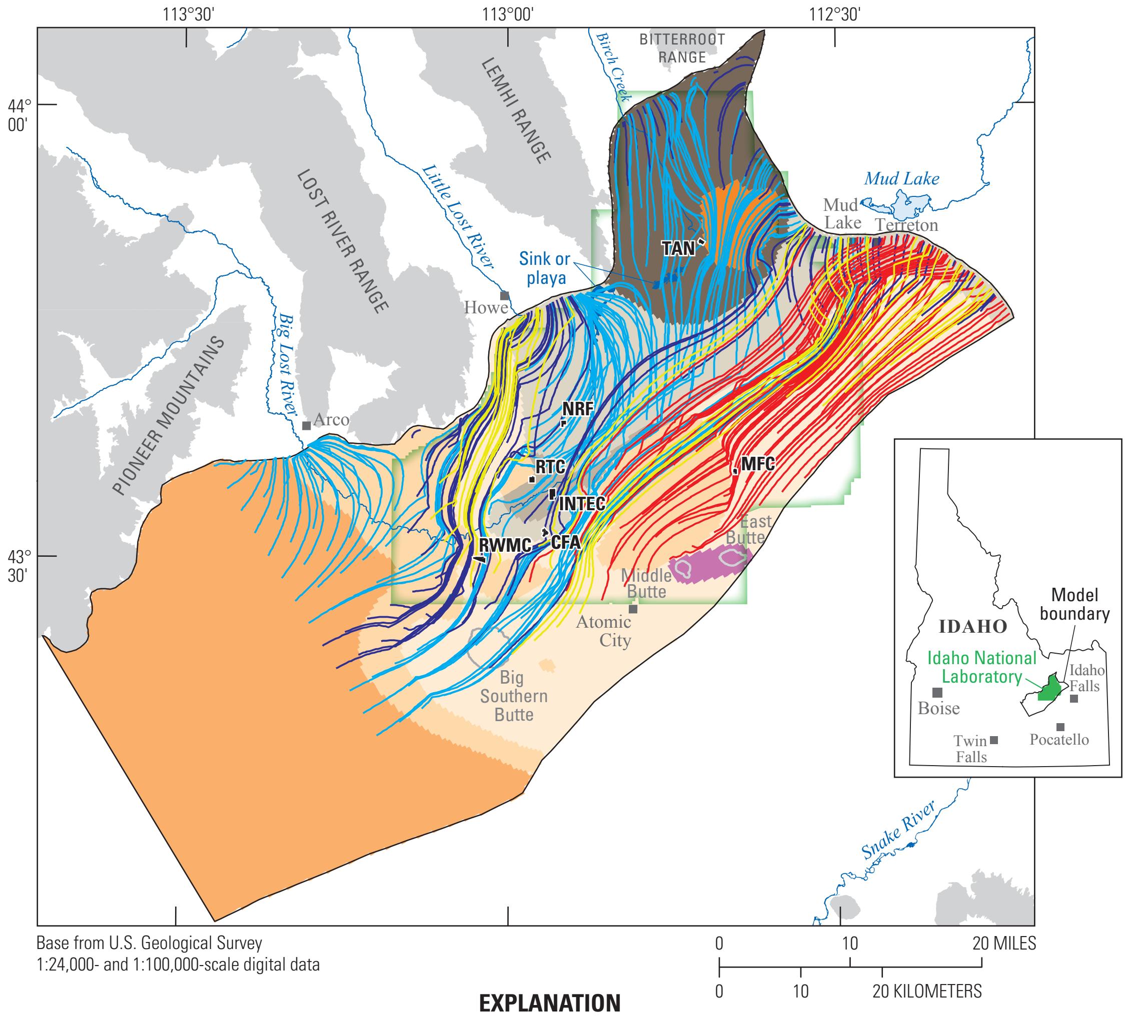


Figure 39. An example of black and white type used in the same figure. On a dark background, black type becomes unreadable. For this reason, white type (also referred to as "drop-out type" or "reverse type") may be used. For computer presentation, the use of white type poses no problem. For offset printing, however, there could be problems with registration. Because printers use CMYK inks and the white type is an area of no ink, it is possible that each ink color could "bleed" into the area of white type if registration is not "spot on."

Note that the shape of the main figure is the same as that shown in the inset map to the left. A north arrow is needed for this figure because latitude and longitude coordinates are not provided. As specified in table 4, county boundaries should be dashed. However, the somewhat convoluted county boundaries—when shown at this scale—are more readable as solid lines and do not detract from the data being presented. For many of the same reasons, State boundaries are shown as slightly thicker and darker solid (not dashed) lines.

The southeastern border of the model area has been broken to accommodate the explanation, which is acceptable because the explanation is not obscuring any data in the Atlantic Ocean. En-dashes are used for minus signs because they are the same length as the minus symbol in the Symbol font, but can be used with the USGS font families of Times New Roman and Univers Condensed. Also, the longer en-dash is easier to see than the shorter minus sign. The word"to" should be used instead of a hyphen. If the word "to" were replaced by a hyphen, the juxtaposition of the hyphen and the minus sign, for example in the first three entries, might be confusing to the reader.

Change in pumpage by county for the Brunswick aquifer system, the Upper Floridan aquifer, and the Lower Floridan aquifer, Florida, Georgia, and South Carolina. Figure modified from Payne and others (2006).



EXPLANATION

Hydrogeologic zones, model layer 1

1—Younger rocks consisting of densely fractured basalt and interbedded sediment, with a sediment thickness of generally less than 11 percent

2—Younger rocks consisting of massive, less densely fractured basalt and interbedded sediment, with a sediment thickness of generally less than 11 percent

3—Intermediate-age rocks consisting of slightly altered fractured basalt and sediment, with a sediment thickness of generally less than 11 percent

4—Intermediate-age rocks consisting of slightly altered fractured basalt and sediment, with a sediment thickness of generally less than 11 percent

11—Younger rocks consisting of densely fractured basalt and interbedded sediment, with a sediment thickness of generally more than 11 percent

22—Younger rocks consisting of massive, less densely fractured basalt and interbedded sediment, with a sediment thickness of generally more than 11 percent

44—Intermediate-age rocks consisting of slightly altered fractured basalt and interbedded sediment, with a sediment thickness of generally more than 11 percent

6—Silicic rocks, including rhyolite domes and andesite

Idaho National Laboratory boundary

Site facilities—Buildings, roads, and surrounding land

CFA—Central Facilities Area

INTEC—Idaho Nuclear Technology and Engineering Center

MFC—Materials and Fuels Complex

NRF—Naval Reactors Facility

RTC—Reactor Technology Complex

RWMC—Radioactive Waste Management Complex

TAN—Test Area North

Model area boundary

Pathlines indicating simulated source areas of groundwater for model layer 2—Color indicates the model layer that pathline was in when it exited the model. Pathlines originated in model layer 2 and were projected onto model layer 1

1 2 3 4

Figure 40. An example of white-outline (or halo) type used in a figure. Site facility names have been "halo"ed so they can be spotted easily in a colorful and busy figure. To keep the base map uncluttered, a gray fill was used for mountain ranges instead of shaded relief.

Pathlines indicating the simulated source areas of groundwater in model layer 1, Eastern Snake River Plain aquifer, Idaho. Particles were distributed uniformly in this layer in the central, northern, and eastern parts of the model area. One particle was released every 4 square miles; 304 particles were released in all. Figure modified from Daniel J. Ackerman (USGS, written commun., February 2010).

Multiple Maps on One Page

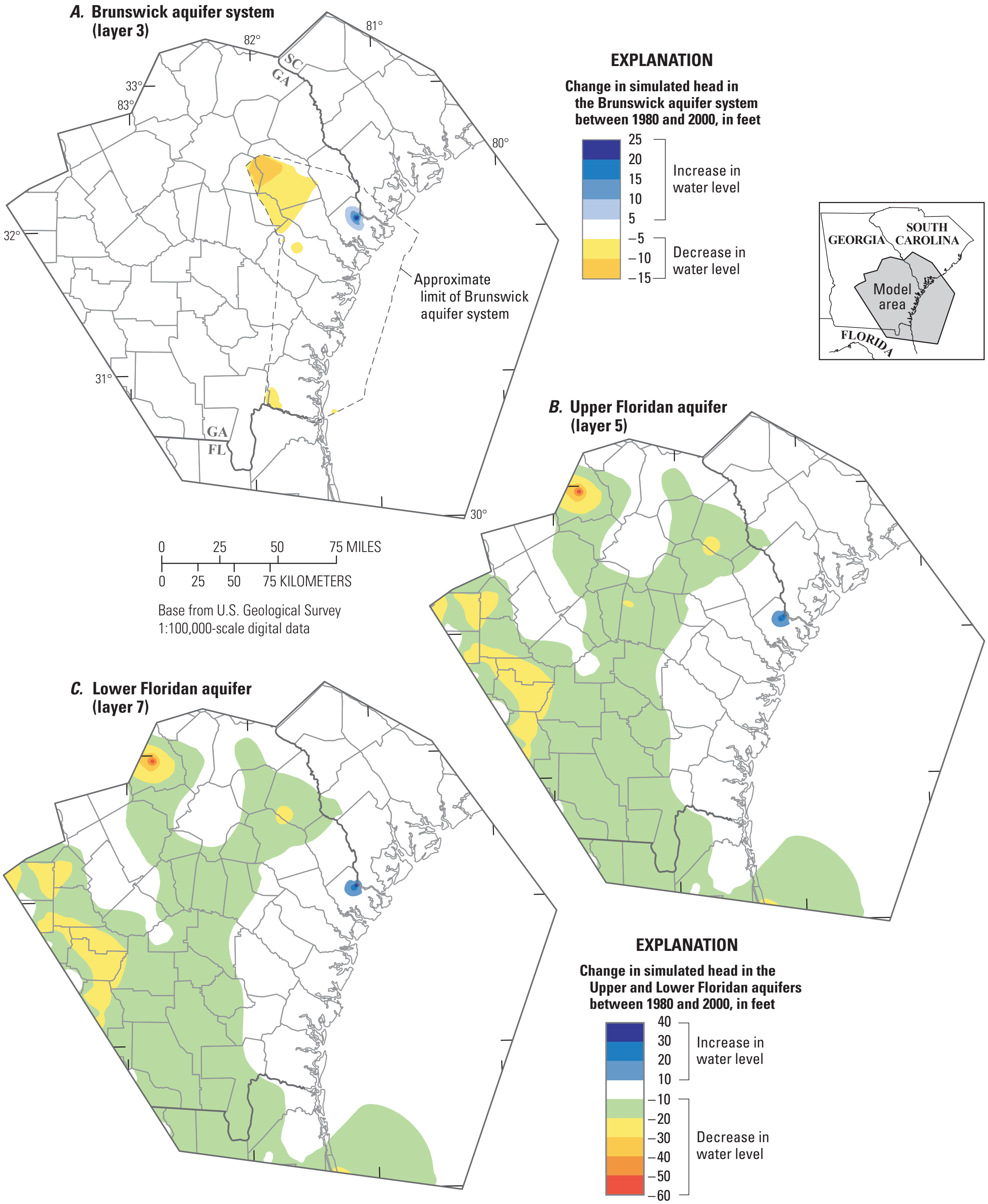


Figure 41 (page 88). Multiple maps shown as a single figure on one page. This figure shows how one north arrow, one base-map credit, and one rake scale (provided the parts of that figure are shown at the same scale) can be used for many parts of one figure. English units and their corresponding metric units are combined onto one rake scale, with the primary units used for the report on top (in this case, English). For more information about rake scales, see the section on rake scales (p. 58).

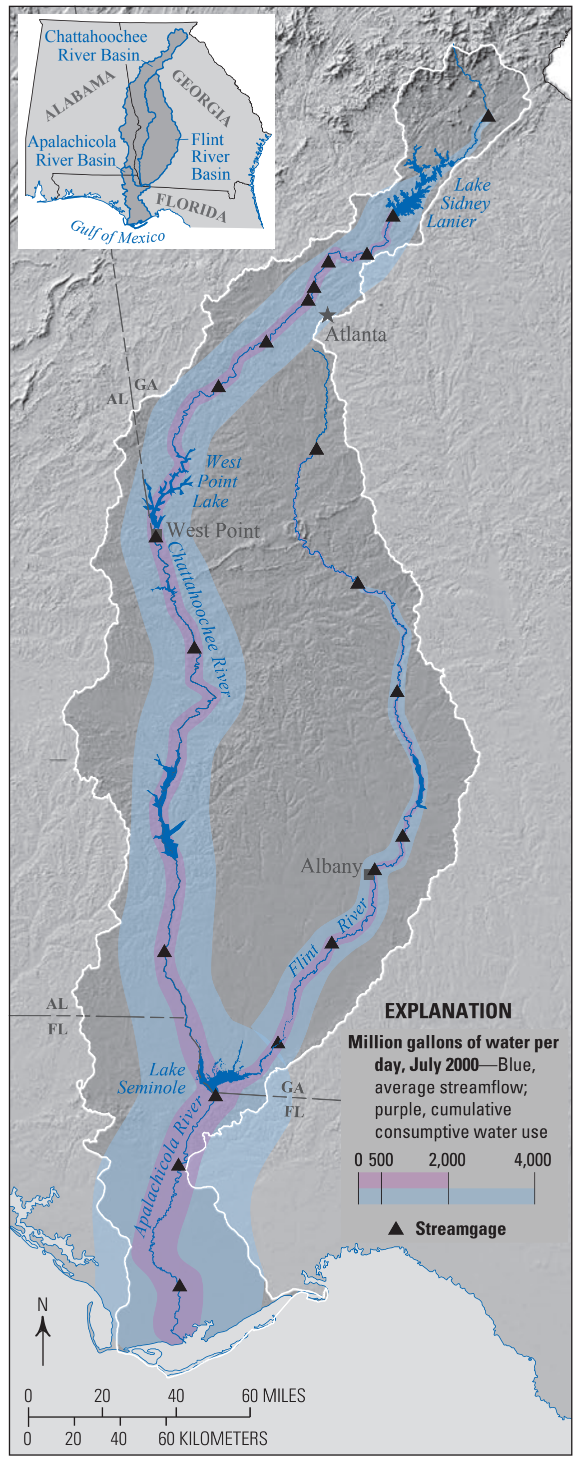
As specified in table 4, county boundaries should be dashed. However, the somewhat convoluted county boundaries—when shown at this scale—are more readable as solid lines and do not detract from the data being presented. For many of the same reasons, State boundaries are shown as slightly thicker and darker solid (not dashed) lines. Finally, notice that there are two deliberately placed explanations showing very different data. The explanation at the top of the figure explains *A*, and the explanation at the bottom of the figure explains *B* and *C*.

Change in simulated water level between 1980 and 2000 for the Brunswick aquifer system, the Upper Floridan aquifer, and the Lower Floridan aquifer, Florida, Georgia, and South Carolina. Figure modified from Payne and others (2005).

Maps with Shaded-Relief Bases

Figure 42 (right). Elements arranged within the neatline of a map to accommodate space constraints. This figure was excerpted from a Fact Sheet with tight space constraints and for this reason, many elements that are usually found outside the neatline were arranged inside the neatline. For example, the inset map was placed at the top left on the shaded-relief background, and the rake scale was placed at the bottom left. A north arrow was substituted for the latitude-longitude grid and corresponding numbers; the general public, a less technical audience, was the intended audience, reinforcing the decision not to show a coordinate system. In addition, the "streamgage" entry in the explanation is centered and not left aligned as a first-order heading.

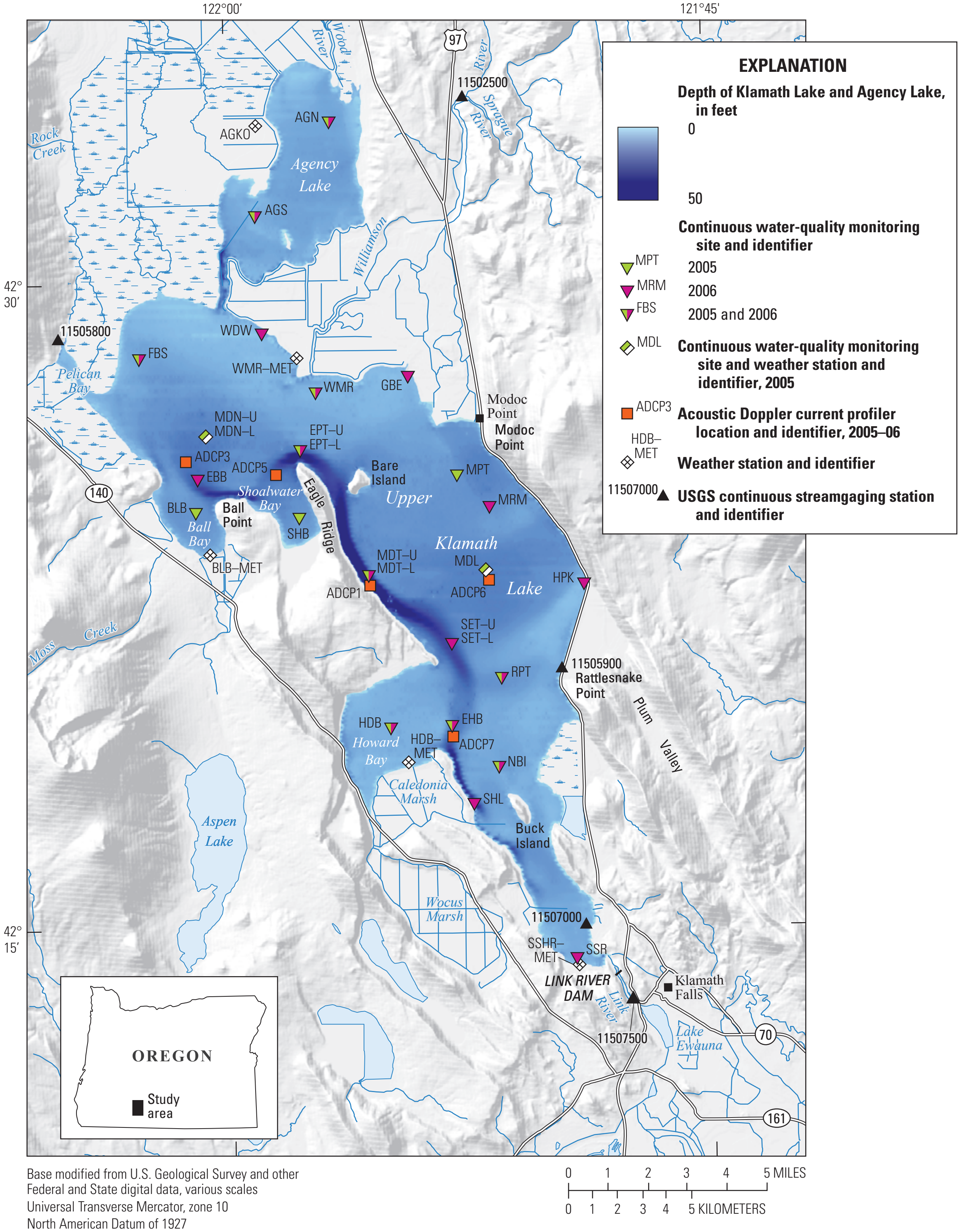
Basin names should be shown in black (table 1), but on the inset map of this figure the illustrator opted to use blue for the basin names in order to match the basin boundaries, which are shown in blue to differentiate them from State lines. In the larger scale map, the shaded-relief topography of the base map is screened outside the white line of the basin boundary so as to highlight the study area. Note that the symbol used for the city of Albany is a solid square (table 6). Because Atlanta is the State capital of Georgia, the illustrator opted to show its location by using a star symbol.



Base modified from U.S. Geological Survey 1:1,000,000-scale digital data
Shaded relief from U.S. Geological Survey 30-meter digital elevation model data

In the Apalachicola–Chattahoochee–Flint River Basin, average streamflow (shown by blue bar in figure) generally increases downstream as basin size increases and as additional water from tributaries and groundwater is added to the flow. Cumulative consumptive water use (shown by purple bar in figure) also increases downstream. (Consumptive water use is defined as water that is withdrawn from a river and is not returned.) Additionally, the type of water use changes with location. The largest consumptive uses are for public water supply in the upper part of the basin (near Atlanta) and for irrigation in the lower part of the basin.

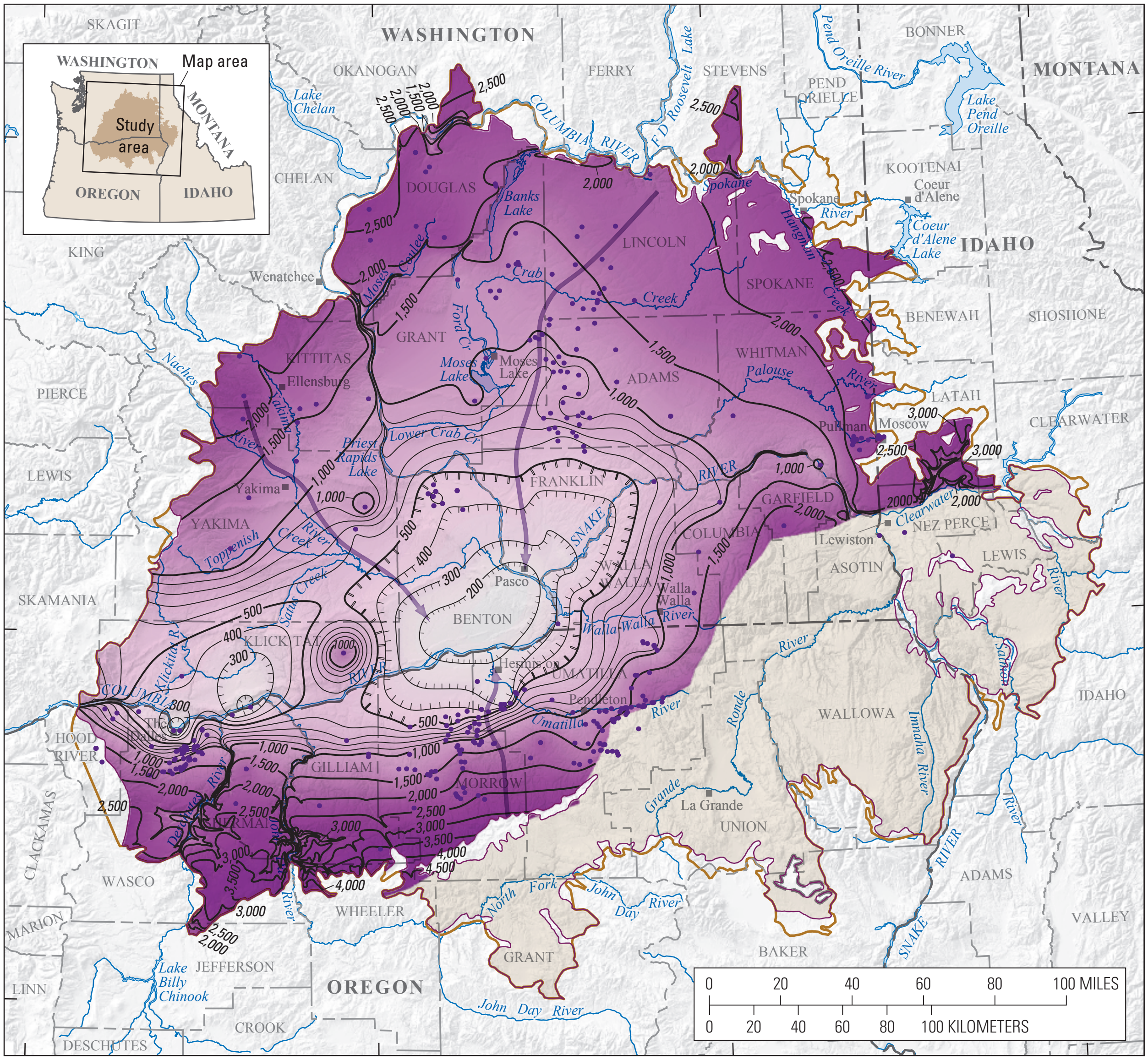
The data presented in this figure show the extreme drought conditions that were present during July 2000. Streamflow in the Apalachicola River was the lowest recorded since 1929, when recordkeeping in this area first began. Extreme droughts are rare but recurring and are the focus of water management and planning. Figure modified from Landers and Painter (2007).



Base modified from U.S. Geological Survey and other Federal and State digital data, various scales
Universal Transverse Mercator, zone 10
North American Datum of 1927

Figure 43. Drainage feature labels shown using two colors of type. Reverse type is used for lake and bay names in the areas where a blue gradient is used for depth. The location map of Oregon is taken from the FGDC Standard (p. A–34–2). A datum statement may be added to the base-map credit if it differs from the required datum statement in the conversion factors table. As shown in this figure, latitude values may be stacked when space is at a minimum.

Location of monitoring sites in Upper Klamath Lake, Oregon. Figure modified from Wood and others (2008).



Base modified from U.S. Geological Survey digital data, various scales
State Plane, Washington, South, FIPS 4602
North American Datum of 1983
North American Vertical Datum of 1988 (NAVD 88)

EXPLANATION

Estimated groundwater altitude—In feet above NAVD 88

67 *5,175* Insufficient data

Columbia Plateau Regional aquifer system

Boundary of Grande Ronde unit

— *200* — **Estimated groundwater contour**—Shows altitude of groundwater. Contour interval 100 feet. Datum is NAVD 88

Groundwater flow direction

• **Well with spring 2009 water-level measurement in the Grande Ronde unit**

Figure 44. Groundwater altitude shown using both index and intermediate contours and a color gradient (ramp) on a shaded-relief base map. The colors on this map use the "multiply mode" in the transparency palette of Adobe Illustrator to allow the shaded-relief base to "show through." The illustrator added shaded relief to the color bars in the explanation to match the colors shown on the map. Note that the term "groundwater" has been used in the explanation because there are both confined (potentiometric surface) and unconfined (water-table surface) conditions in the study area; "groundwater" seemed more appropriate and less confusing as the illustration was intended for resource managers and lay public.

Estimated groundwater altitudes and locations of wells for the Grande Ronde unit, Columbia Plateau Regional aquifer system, Washington, Oregon, and Idaho. Figure modified from Snyder and Haynes (2010).

Cross Sections, Stratigraphic Columnar Sections, and Correlation Charts

Introduction

A geologic or hydrogeologic cross section is a representation of geologic, hydrologic, and geographic features that exist at and beneath the land surface along a vertical plane (see fig. 45 for specifications). Cross sections depict features that often can be seen in a section of rock that is exposed when a road is cut through a hill—features such as the configuration of the land surface, structure and lithology of the rocks, and surface drainage.

A hydrologic cross section, on the other hand, is a representation of the features that exist at and beneath the surface of a body of water, as viewed downstream with the left bank on the left side of the section. These cross sections sometimes show the outline of a dry streambed and indicate the depth of water during a previous period of high water flow (see fig. 46 for specifications).

A stream profile represents features beneath the surface of a body of water as viewed from either bank. One end is always higher than the other end because it shows the longitudinal profile of a stream (see fig. 47 for specifications).

Much of the information shown on geologic, hydrogeologic, and hydrologic cross sections is the same. All cross sections must show vertical and horizontal scales, a vertical exaggeration note if there is vertical exaggeration, and a vertical datum. The vertical datum (1) may be labeled in the vertical axis (fig. 51*A*), (2) may be placed below the cross section if the datum is not included as part of the vertical axis (figs. 51*B* and 53), or (3) may be placed below the cross section if zero—representing the datum—is labeled in the vertical axis (fig. 52).

The vertical datum (1) may be labeled in the vertical axis, (2) may be placed below the cross section if the datum is not included as part of the vertical axis, or (3) may be placed below the cross section if zero—representing the datum—is labeled in the vertical axis.

Page 96 shows options for labeling vertical axes on cross sections to accommodate both English and metric units. The line of intersection of the land surface with the plane of a cross section, as shown on a map, is called the line of section (or trace). Information on how to label these lines of section is presented on page 97.

A stratigraphic columnar section (see p. 98 for specifications) is a “graphic representation on a vertical strip of the sequence of rock units that occurs in an area or at a specific locality. Thicknesses are drawn to scale, and lithology is indicated by standard or conventional symbols [patterns], usually supplemented by brief descriptive notes indicating age, rock classification, fossil contents, etc.” (Jackson, 1997, p. 128). A correlation chart (see p. 99 for specifications) “shows an author's interpretation of rock units and their ages as related to units that other workers have recognized elsewhere” (Hansen, 1991, p. 52, 54).

As was done in the map section, many pages of examples demonstrating the specifications described in the generic cross sections are shown. Note the variability among the cross sections—units (both hydrologic and geologic) delineated by screened patterns and various colors; red and black faults; black and magenta contacts; geology extending 2 kilometers above the land surface and 20 meters below; vertical axes labeled on one side (p. 101), on both sides (p. 102), or not at all (p. 106). An explanation for a cross section is necessary if unlabeled data, colors, or patterns are shown. Notice that if a map is shown with a cross section, the line of section is shown on the map (see p. 103–105). Examples of stratigraphic columnar sections are shown on pages 108 and 109. Note the flexibility in format relative to the “recommended” columnar section shown on page 98. Variability of design and flexibility of format are dependent on the good judgment and discretion of the illustrator.

General Information for Cross Sections—Geologic and Hydrogeologic

Orientation

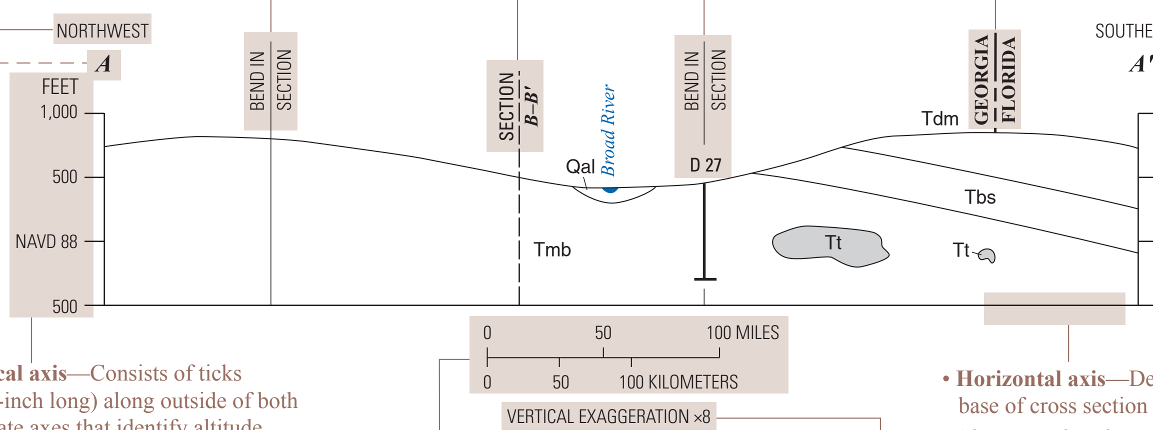
- Show either direction term or cross-section letter. Both may be used at author's discretion
- Placed and centered above highest point of vertical axis
- **Direction term**—Used with generalized sections. Univers 47 Condensed Light, 7 pt, uppercase
- **Cross-section letter**—Used when line (trace) of section is shown on a map. Times New Roman Bold Italic, 8 or 9 pt, uppercase

- **Line identifying where two traces intersect on a map**—Shown as a dashed (7-pt dash and 1.5-pt gap) line with a lineweight of 0.5 pt
- Term “SECTION”— Univers 57 Condensed, 7 pt, uppercase
- Cross-section letters—Times New Roman Bold Italic, 7 pt, centered underneath “SECTION”

- **Line identifying political divisions**—Between States and counties, for example
- Use appropriate line symbol from table 4
- Use appropriate font from table 1
- Spell out State names. Use postal abbreviations if necessary
- If two county names are shown, each name is followed by the word “County”

- **Bend-in-section line**—Indicates location where trace of section on a map shows a significant change in direction
- Shown as a solid line with a lineweight of 0.3 pt
- Univers 47 Condensed Light, 7 pt, uppercase
- Type placed above land surface

- **Drill hole (well) identifier**—Univers 57 Condensed, 7 pt
- Type placed between land surface and bend-in-section note



- **Vertical axis**—Consists of ticks (0.10-inch long) along outside of both ordinate axes that identify altitude
- Top and bottom of axis should end on a numbered tick
- Scales at each end of section will be same height; height is determined by next numbered division above highest elevation on profile
- Axis unit of measurement (for example, FEET)—Univers 47 Condensed Light, 1 pt larger than axis labels, uppercase
- Axis labels (numbers and words)—Univers 47 Condensed Light, 7 or 8 pt, uppercase
- Numbers are placed outside and centered on ticks (numbers may be shown at both ends of cross section)
- Use commas in numbers greater than 999
- On left axis, unit of measurement and numbers are right justified
- On right axis, unit of measurement and numbers are left justified
- Vertical datum is indicated by a zero (0) or “SEA LEVEL” (for geology reports) and by “NAVD 88” or “NGVD 29” (for water reports)
- If datum is not included in vertical scale, a datum note is required. It should be of the form “DATUM IS NAVD 88” and should be placed with vertical exaggeration note beneath section

- **Rake scale**—Preferably will be centered below and outside cross section
- Horizontal scale should be identical to the map that shows the trace, where possible. If not, scale should be a whole-number multiple of the scale of the map (for example, 2 or 3 times—not 1.7 times)
- See section on general information for maps for details on creating rake scales

- **Vertical exaggeration note**—Univers 47 Condensed Light, 7 pt, uppercase
- If vertical exaggeration is given, preferably center note below and outside cross section
- If vertical exaggeration exceeds ×20, the notation “VERTICAL SCALE GREATLY EXAGGERATED” should be used
- If vertical exaggeration is not given but is evident, add phrase “NOT TO SCALE” to lower left corner of cross section

- **Horizontal axis**—Defines base of cross section
- Always enclose base of cross section with a line
- Should not have ticks

Additional labeling information

- If an explanation is needed, follow general information for explanations shown on page 28
- Formations reaching surface of cross section should be labeled above section
- Leader lines should be used only to clarify a congested area
- Labels for formations beneath surface will be centered within formation area except where insufficient pattern would be left to define area

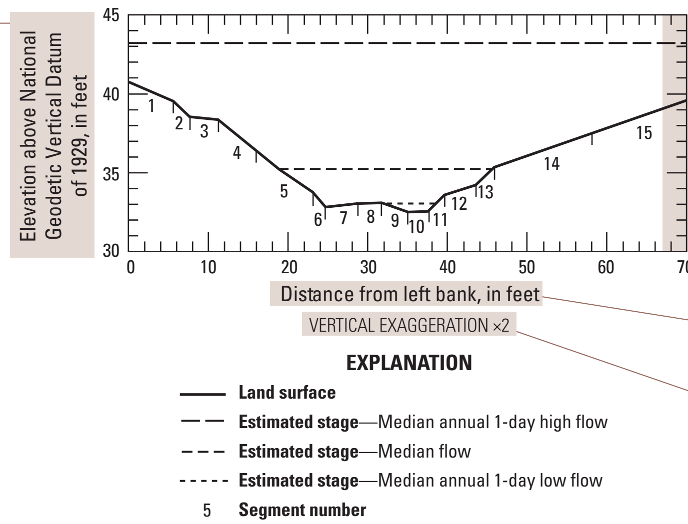
Figure 45. A generic cross section (geologic and hydrogeologic) for use in page-size illustrations.

General Information for Cross Sections—Hydrologic

(For any specifications not listed below, use those for generic cross section listed on facing page)

- **Cross section**—Represents features beneath the surface of a body of water as viewed downstream with the left bank on the left side of the section
- Boxed in, with ticks on the inside of all four axes
- Type styles: Use same type style for axes as those used for graphs; within section, use same type styles for labeled features as those used for maps (see table 1)
- Lineweights: Use same lineweight for axes as those used for graphs; within section, use same lineweights for features as those used for maps (see table 4)
- Features in a cross section should be labeled in cross section or described in explanation

- **Vertical axis**—Shows elevation above or below a datum: National Geodetic Vertical Datum of 1929, North American Vertical Datum of 1988, or arbitrarily assigned
- Datum should be stated in vertical axis label and spelled out
- If a datum statement is not included in vertical axis label, it should be placed beneath vertical exaggeration note



- If **major and minor ticks** are shown, label only major ticks
- Minor ticks should not be more than one-half the length of major ticks
- A good length for major ticks is 0.10 inch, and a good length for minor ticks is 0.05 inch
- **Horizontal axis**—Shows distance from left bank
- If **vertical exaggeration** exceeds ×20, the notation "VERTICAL SCALE GREATLY EXAGGERATED" should be used

Figure 46. A generic hydrologic cross section for use in page-size illustrations.

General Information for Stream Profiles

- **Stream profile**—Represents features beneath the surface of a body of water as viewed from either bank. Profiles are always higher at one end
- Horizontal axis is almost always distance upstream from some stated location. Zero should always be in the downstream direction of the profile. A location for the profile should be stated in the axis label
- Other specifications same as for hydrologic cross section, listed above

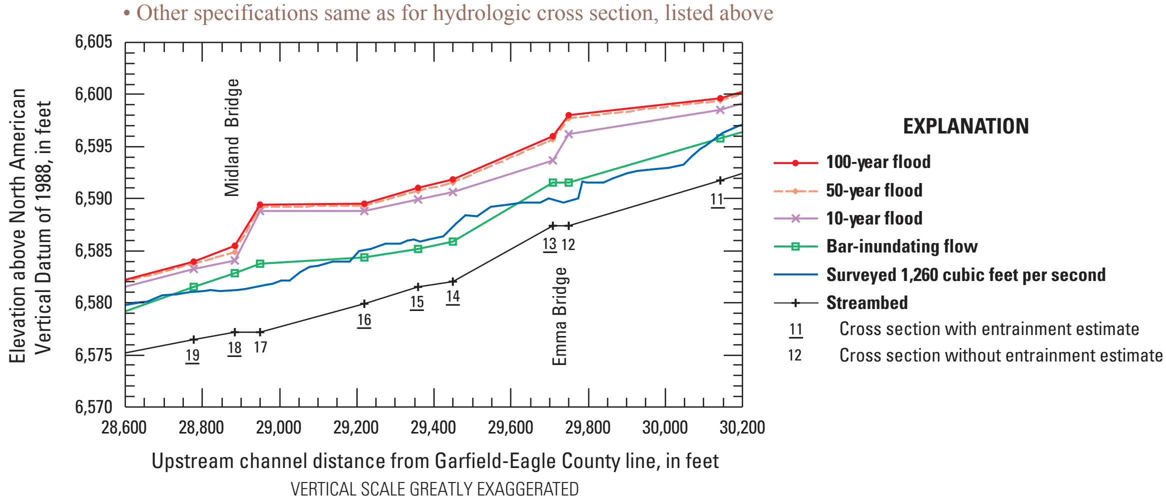


Figure 47. A generic stream profile for use in page-size illustrations.

Options for Labeling Vertical Axes on Geologic and Hydrogeologic Cross Sections

In the generic cross section, both vertical axes have ticks but only the left axis is labeled. This is the suggested method, but there are other acceptable options. In the examples below, ticks are shown on both sides of the cross section, and both sets of ticks align. In example *A*, both axes are labeled using English units. If metric units are used in the report, both axes may be labeled using metric units.

Also, if the map that is associated with the cross section has a base with English units (for example, 1:24,000 scale), then English units should be used for the cross section. Conversely, if the map that is associated with the cross section has a base with metric units (for example, 1:100,000 scale), then metric units should be used for the cross section.

Sometimes, however, authors wish to show both units on their cross sections. Example *B* shows meters on the left vertical axis and feet on the right vertical axis. Note that the interior ticks on the left vertical axis align with the labeled ticks (feet) on the right vertical axis, and that the interior ticks on the right vertical axis align with the labeled ticks (meters) on the left vertical axis. Example *C* shows a metric scale off to the right side of the section. The datums (NAVD 88) on both scales align. Interior ticks are shorter than the exterior ticks (*B* and *C*).

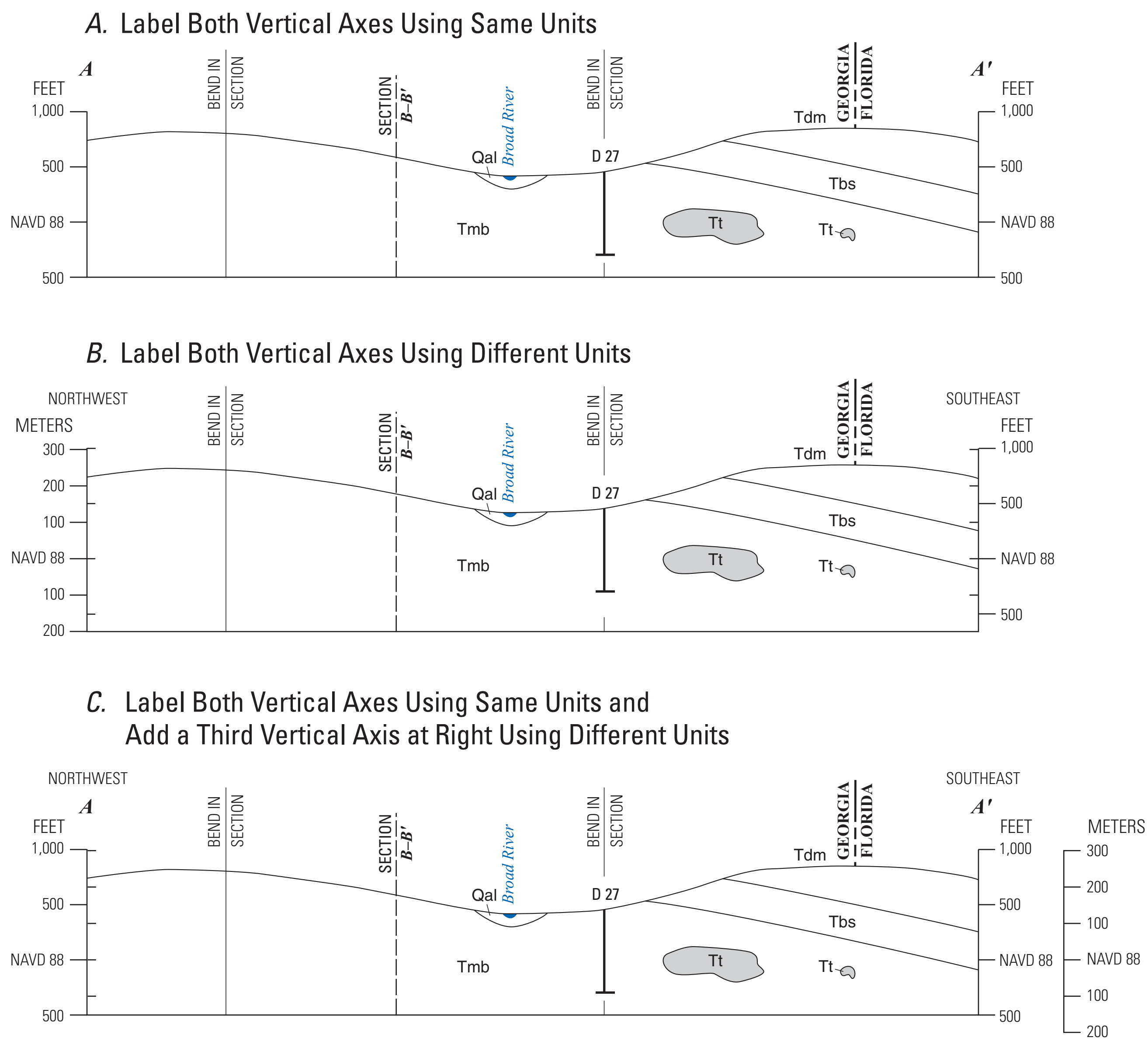
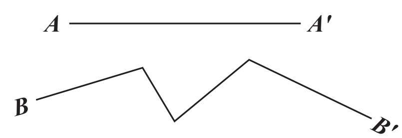


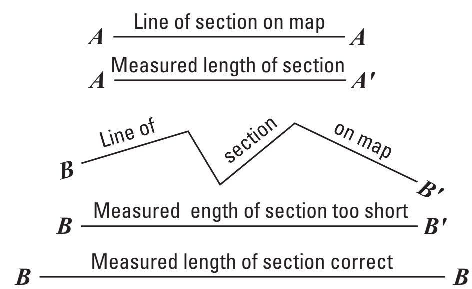
Figure 48. Options for labeling vertical axes on cross sections.

Labeling Lines of Sections (or Traces) on Page-Size Maps

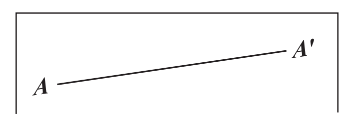
The line of intersection of the land surface with the plane of a geologic or hydrogeologic section, as shown on a map, is called the line of section (sometimes referred to as a trace). The line of section may be one continuous straight line (*A–A′*) or a series of short straight-line segments, which generally connect locations of data such as wells or test holes, and which form a crooked or zigzag line (*B–B′*).



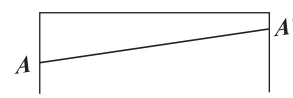
If the line of section on the map consists of one continuous straight line, the measured length of the cross section is the same length (*A–A′*). If the line of section on the map consists of a series of segments that forms a zigzag line, the measured length of the cross section is the sum of the individual segments (*B–B′*).



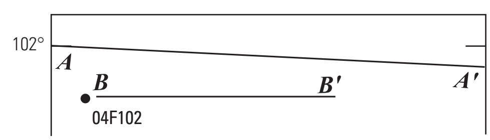
The basic rule for labeling lines of sections on maps is to center the cross-section letters at the ends of the line and align them with the plane or direction of the line, which has a lineweight of 0.6 point. Cross-section letters are set in Times New Roman Bold Italic, 8 or 9 point (see table 1).



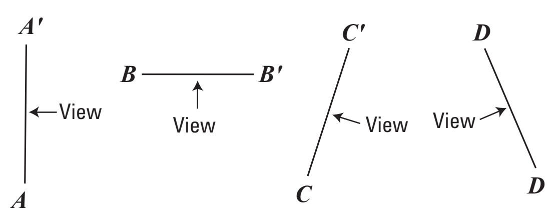
If the line of section extends to the limits of the map (neatline), cross-section letters should be placed outside the limits and centered on the line.



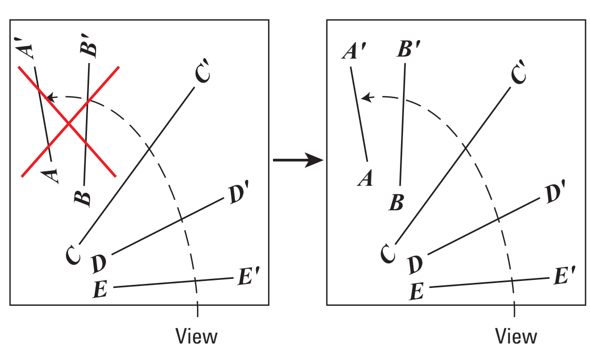
If there is an interference at either end of the section line, solve the letter placement at that end of the line and make the same adjustment at the other end (*A–A′*). The entire line is like a symbol and should be balanced. If the cross-section letter cannot be placed at the end of the line, try to place it above the line of section (*B–B′*).



Orient the map with north at the top. Viewing the line of section as shown in the figure to the right, assign the letter designation to the left end of the line of section and the letter-prime designation to the right end of the line of section.



If several lines of sections are shown on one map, assign sequential sets of letters to the section lines: *A–A′*, *B–B′*, *C–C′*, and so forth. A common orientation of the sections should be maintained, all viewed from one direction. To avoid placing type on its back, the type should be placed so that it is aligned with the illustration.



General Information for Stratigraphic Columnar Sections

- **Stratigraphic columnar section**—Compiled for large areas to show stratigraphic unit name, its position by geologic system, its rock type, and its thickness
- A detailed lithologic description may be included
- Lithologic patterns from the FGDC Standard indicate rock type
- Standard outcrop form is used for cliff, ledge, and slope (see page 108, for example)
- Type styles: Use stratigraphic and correlation chart type styles (see table 1)
- Lineweights: Use neatline lineweight 0.5 pt (see table 4). Division lines between descriptive matter should be angled when type will not fit in area opposite lithologic pattern. Angled lines should be a continuation of contact lines between formations
- The format, as shown below, should be followed as closely as possible; however, variations of this format are acceptable (see pages 108–109, for examples)
- Stratigraphic columns generally are shown as figures even if they lack graphical elements, such as lithologic patterns or unconformity lines. Stratigraphic columns may be treated as tables. Within a single report, stratigraphic columns should be treated in a similar manner

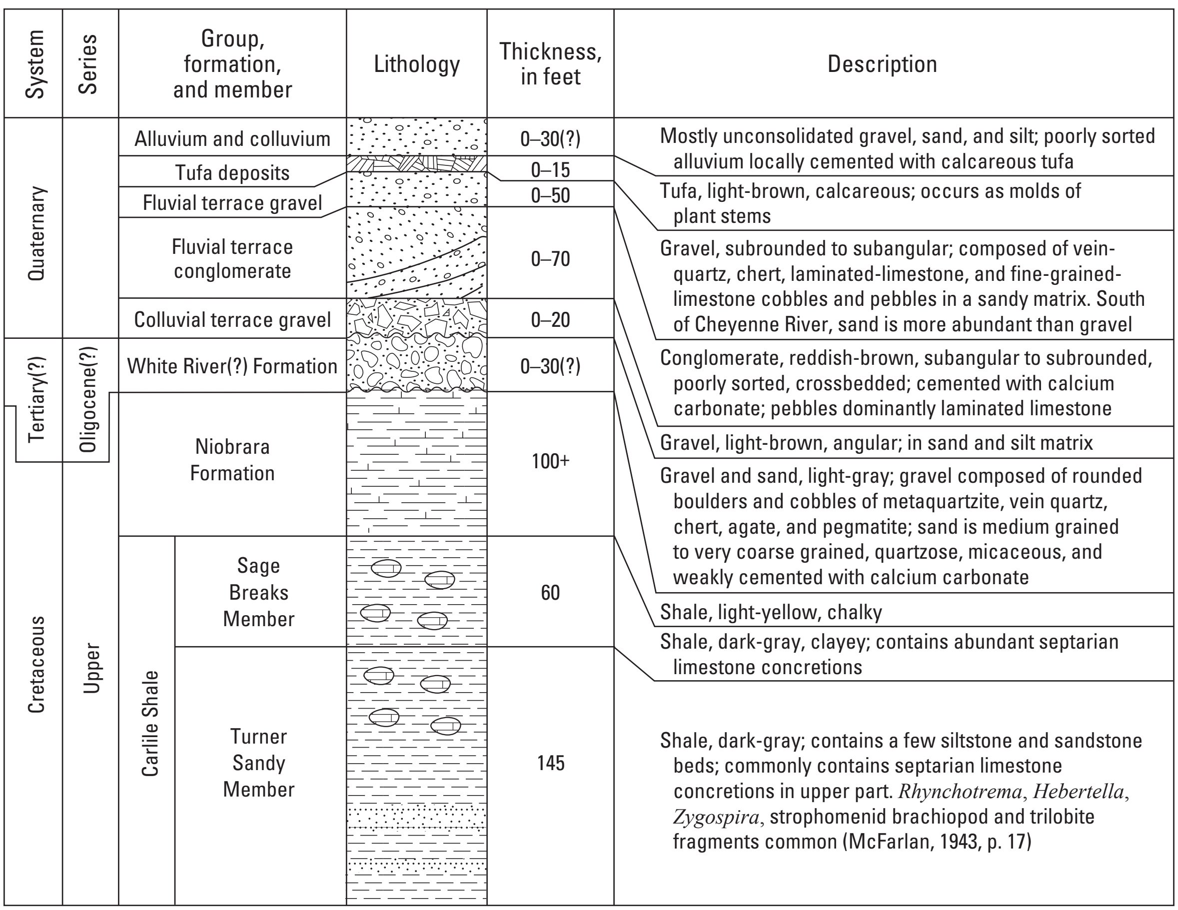
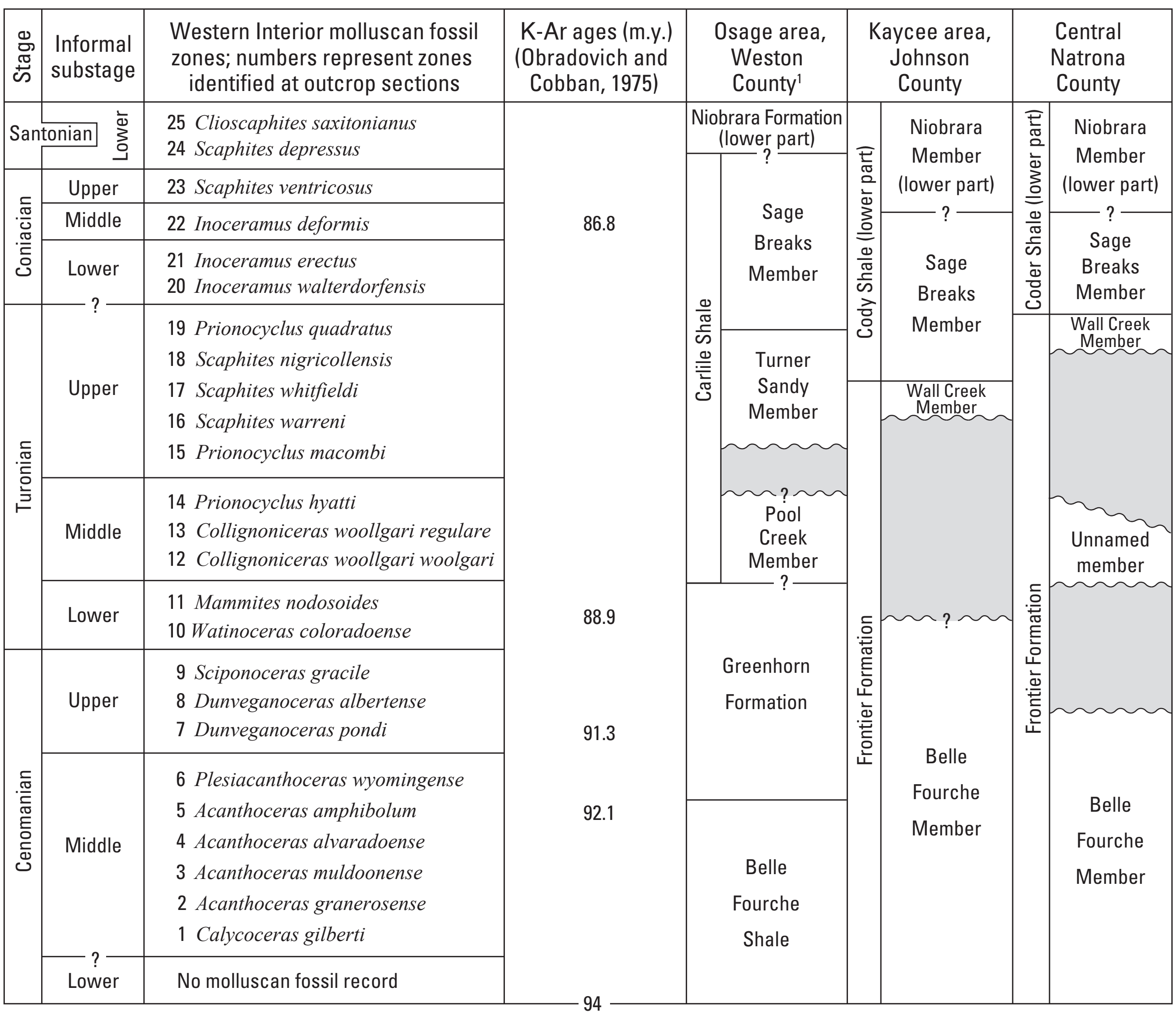


Figure 49. An example of a stratigraphic columnar section for use in page-size illustrations.

General Information for Correlation Charts

- **Correlation chart**—Shows author's interpretation of rock units and their ages as related to units that other workers have recognized elsewhere
- Time terms are usually placed in the left columns of the chart
- Hierarchy or stratigraphic rank is shown by placing the largest or highest rank at the left side of each column
- Units are listed in order of increasing age, youngest at the top and oldest at the bottom
- All boxes for rock units should be identified by name, whether names are formal (Frontier Member) or informal (unnamed member)
- Missing rock can be shown either by shading or by a diagonally or vertically ruled line pattern. No text is needed
- Wavy lines connote unconformities
- Type styles: Use stratigraphic and correlation chart type styles (see table 1). First letter of first word in each entry, whether formal or informal, is capitalized
- Abbreviations should be avoided, but if space is a problem, a standard abbreviation may be used, the box may be enlarged to accommodate the lettering, the point size of the type may be reduced, or a footnote may be used
- Lineweights: Use neatline lineweight 0.5 pt (see table 4)

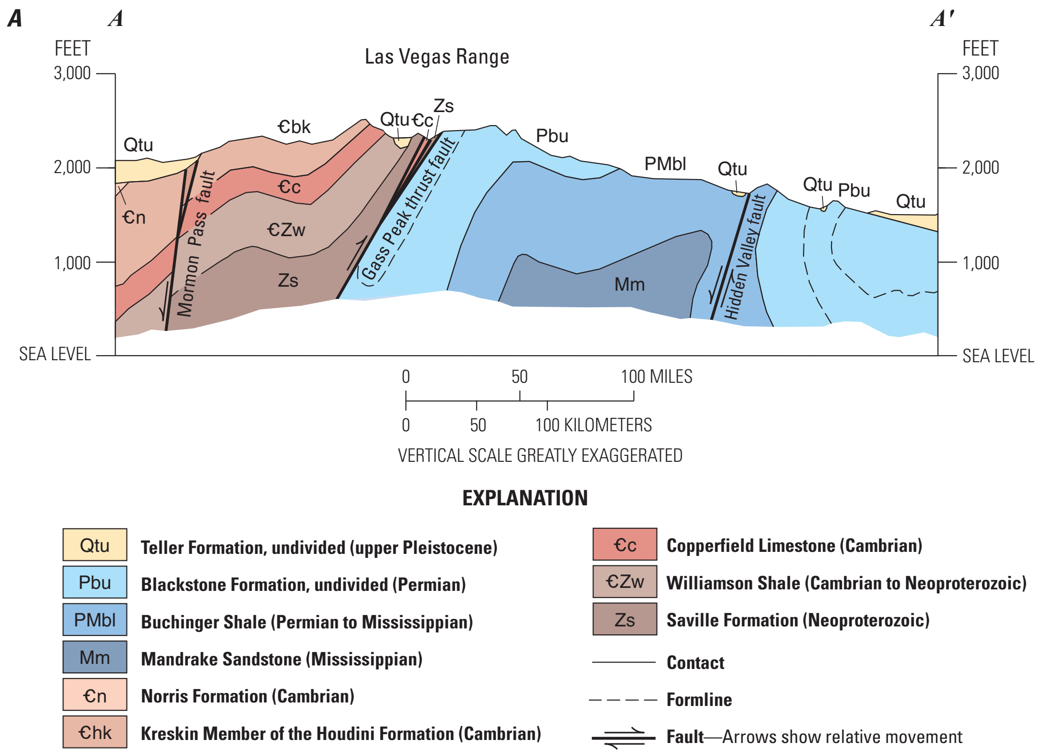


[1]Age of basal contact of Niobrara Formation from Evetts (1976, p. 121).

Figure 50. An example of a correlation chart for use in page-size illustrations. m.y., million years.

Examples

Cross Sections



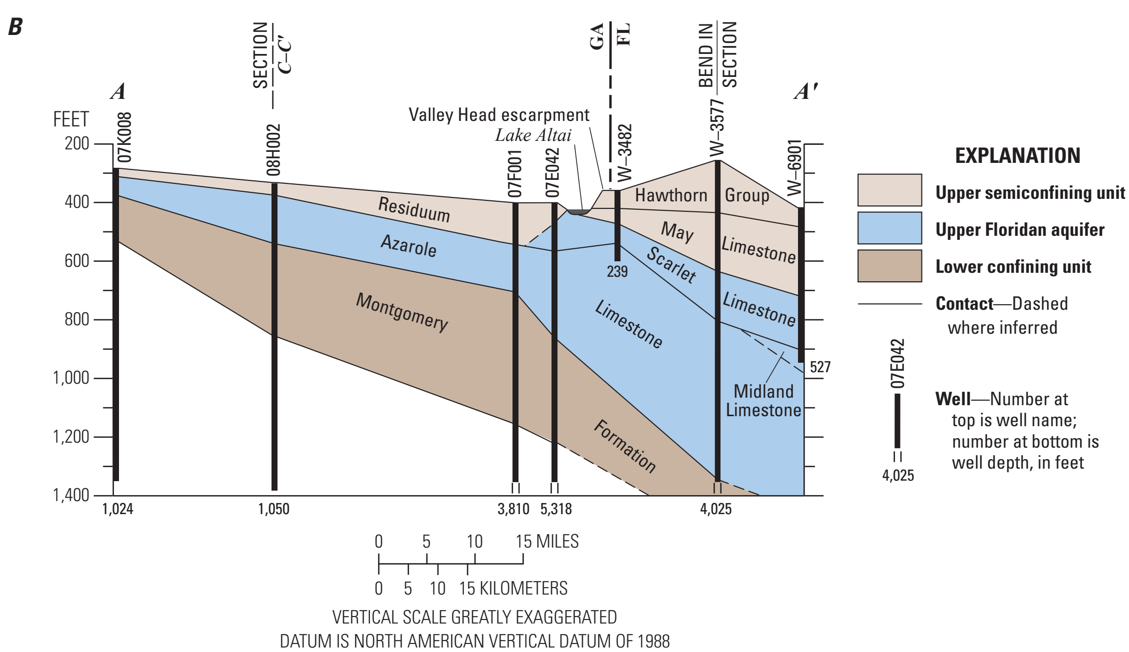
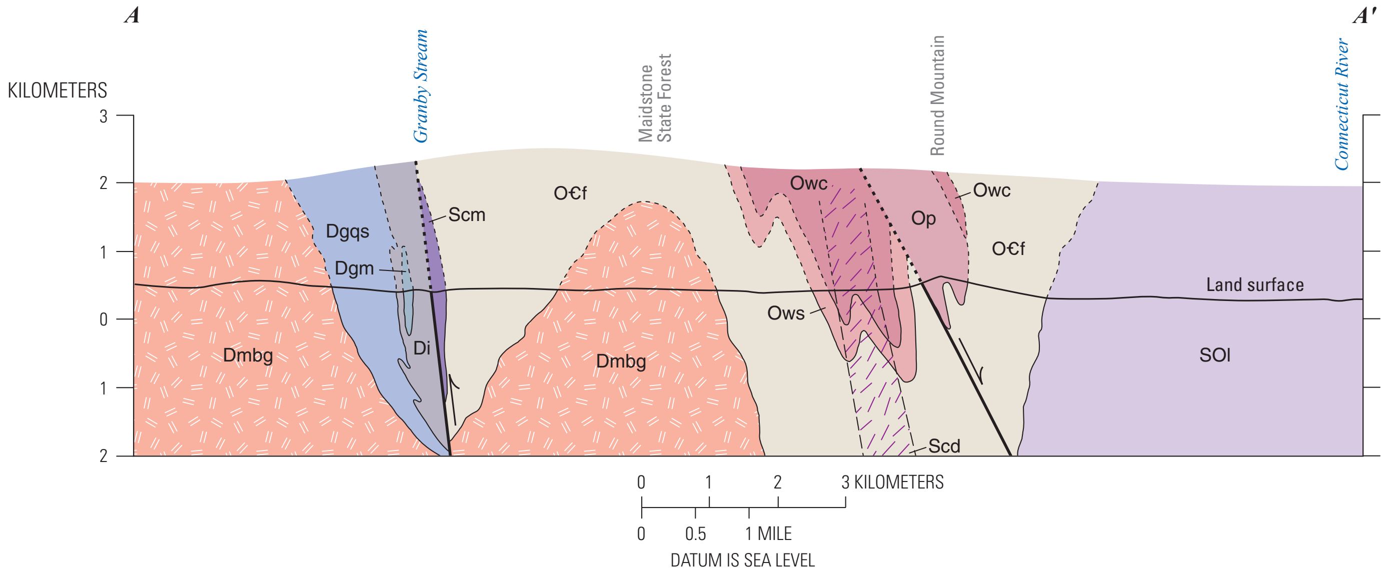
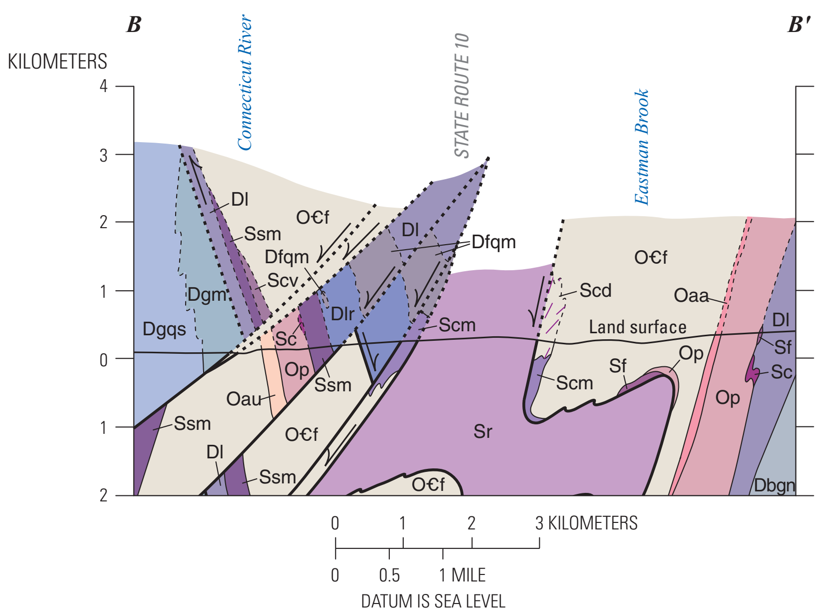


Figure 51. Examples of a geologic cross section (*A*) and a hydrogeologic cross section (*B*). A scratch boundary (no bounding line) defines the lowermost extent of the portrayed geology. The “Lake Altai” label is black, even though it is a water feature. Because the upper Floridan aquifer is shown in blue, the illustrator opted to show all labels and leaders in black to minimize confusion.





EXPLANATION

- Dgm — **Meetinghouse Slate Member of the Gile Mountain Formation (Lower Devonian)**
- Dmbg — **Maidstone pluton (Devonian)**
- Dfqm — **Fairlee Quartz Monzonite (Early Devonian)**
- Dbgn — **Bethlehem Gneiss (Early Devonian)**
- Dgqs — **Quartzite and metapelite member of the Gile Mountain Formation (Lower Devonian)**
- Di — **Ironbound Mountain Formation (Lower Devonian)**
- Dl — **Littleton Formation (Lower Devonian)**
- Dlr — Metarhyolite
- Sf — **Fitch Formation (Upper Silurian)**
- Scv — **Unnamed volcaniclastic and metasedimentary member of the Waits River Formation (Silurian)**
- Ssm — **Sawyer Mountain Formation (Silurian)**
- **Comerford Intrusive Suite (Silurian)**
- Scm — Metagabbro, metadiorite, and metatonalite
- Scd — Metatholeiitic mafic dikes
- Sr — **Rangeley Formation (Lower Silurian)**
- Sc — **Clough Quartzite (Lower Silurian)**
- SOl — **Granitic rocks of the Lost Nation Pluton (Early Silurian to Late Ordovician)**
- Op — **Partridge Formation (Upper Ordovician)**
- Oau — **Ammonoosuc Volcanics, undivided (Upper and Middle Ordovician)**
- Oaa — Metamorphosed andesitic and basaltic tuff
- Owc — **Volcanic chert of the Washburn Brook Formation (Ordovician)**
- Ows — **Sedimentary breccias of the Washburn Brook Formation (Ordovician)**
- O€f — **Foster Hill Formation (Ordovician to Middle Cambrian)**
- **Contact**—Dashed where inferred; dotted where above land surface
- **Fault**—Dotted where above land surface; arrow shows relative movement

Figure 52. Two geologic cross sections from the bedrock geologic map of Vermont (unpub. data). All lines projected above the land surface (including faults) use the concealed-line convention—dotted lines. All geographic features (mountains and rivers) and cultural features (routes and parks) have been labeled "high" above the land surface. Labeling above the area colored by geologic units is necessary in this case because much of the area near the land surface is cluttered with information. Generally, try to avoid placing some labels near the land surface and other labels high above the land surface in the same cross section.

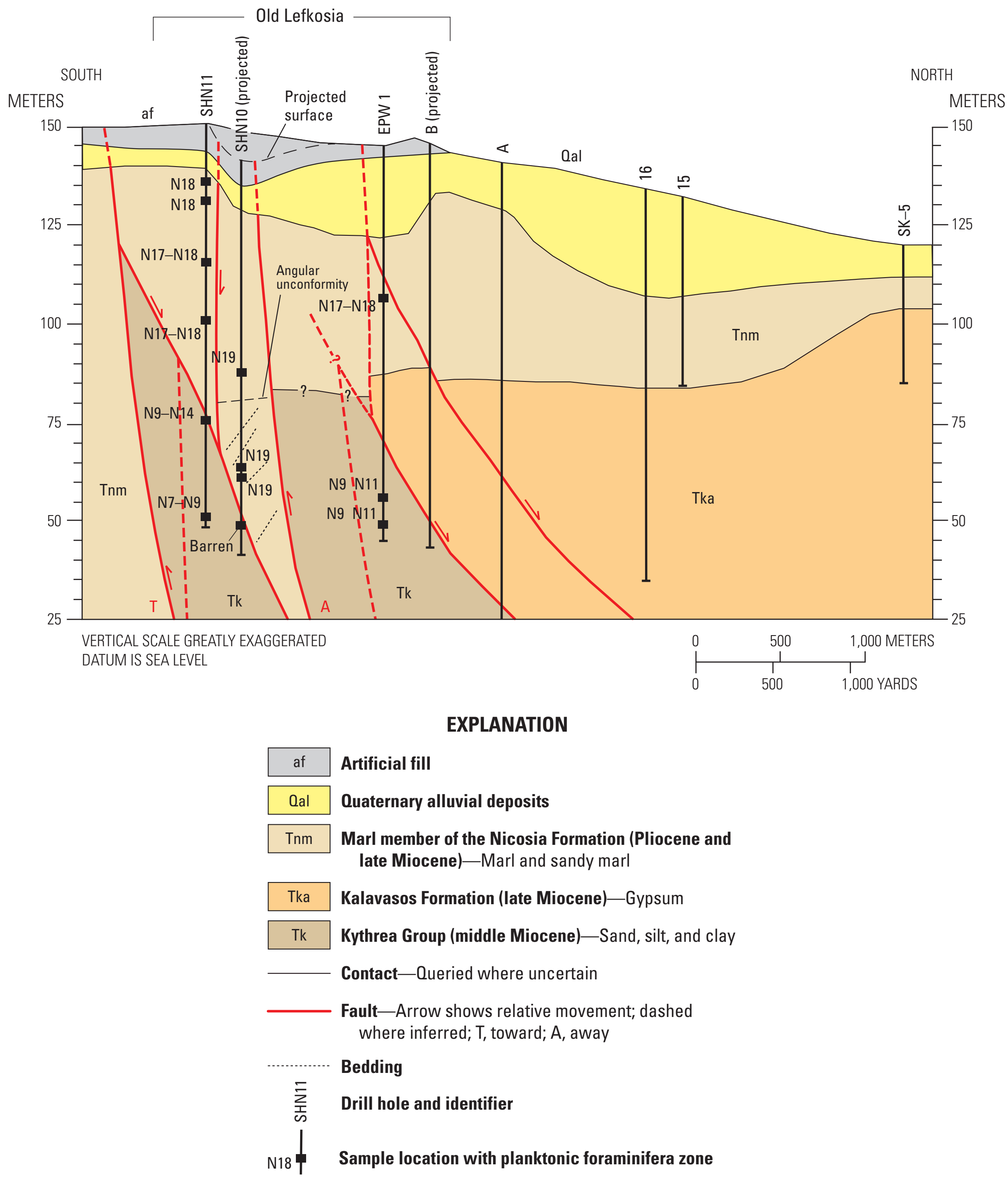


Figure 53. Cross section showing fault lines in red. In other cross sections in these standards, faults are shown using black lines. Because black is used for contact lines and drill holes in this figure, the illustrator opted to show the faults in red to aid readability. As per GPO (2008, p. 64), “Metropolitan Lefkosia, Cyprus” (uppercase “M”), but “Lefkosia metropolitan area, Cyprus” (lowercase “m”).

Generalized north-south-trending cross section through the northern part of Metropolitan Lefkosia, Cyprus, showing the complexity of subsurface stratigraphy and deformation along the Ovgos fault zone. Figure modified from Harrison and others (2008).

Cross Sections and Accompanying Maps Showing Lines of Section

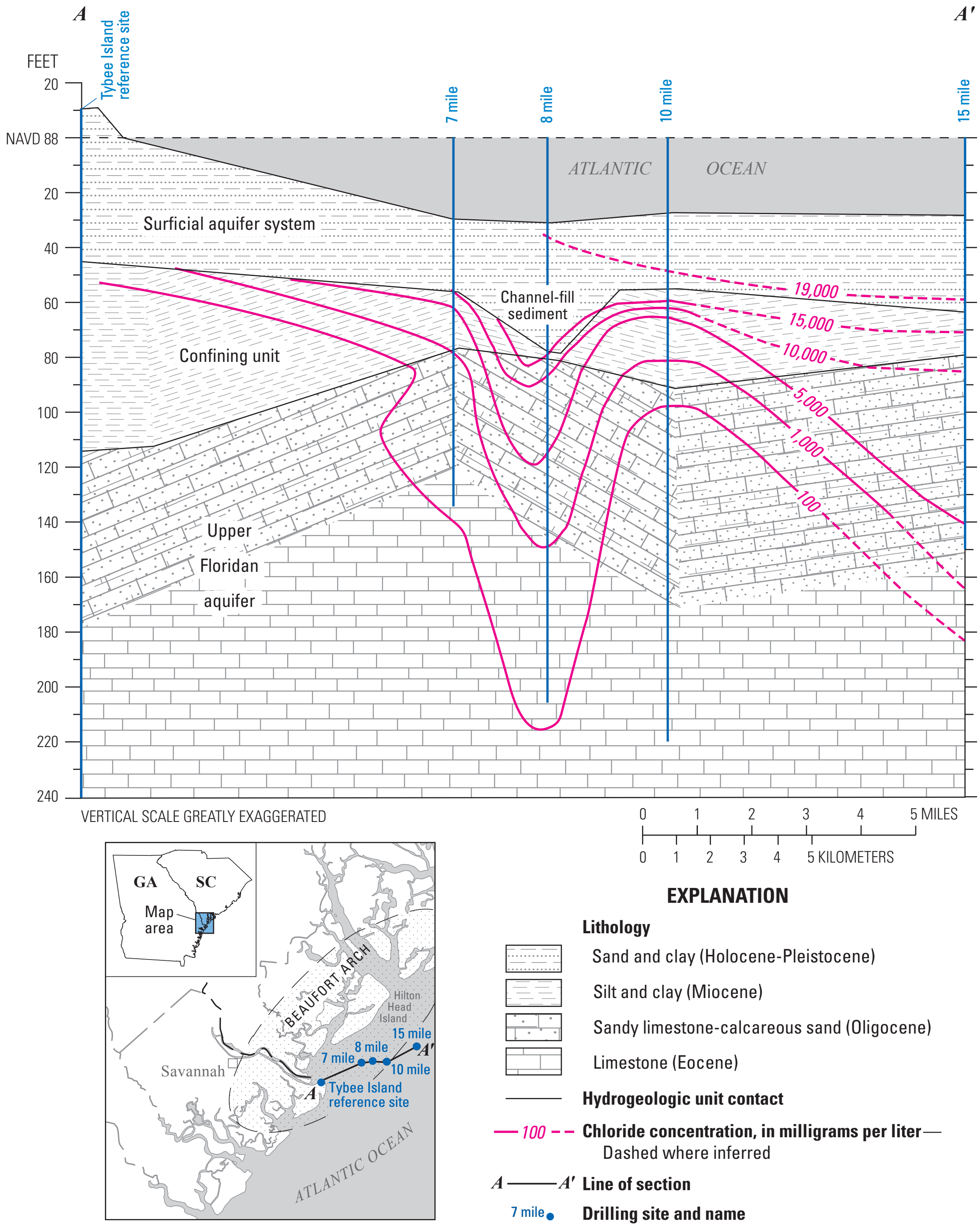


Figure 54. Cross section showing screened and combined patterns. Lithologic patterns are screened so that the magenta-colored lines of chloride concentration "pop." Use patterns from the FGDC Standard. If a pattern is needed that does not exist in these standards, it may be necessary to combine two of the existing patterns from the standard or create a new one. In this figure, pattern no. 627 (limestone) was combined with pattern no. 613 (calcareous sandstone) to create the pattern needed for the sandy limestone-calcareous sand unit. The use of the phrase "vertical scale greatly exaggerated" indicates that the vertical exaggeration in this figure is greater than 20 times.

Hydrogeologic cross section *A–A′* showing the distribution of chloride from the reference site at the northern end of Tybee Island, Ga., to the 15-mile site on the Beaufort arch, seaward of Hilton Head Island, S.C. Figure modified from Falls and others (2005) and Provost and others (2006).

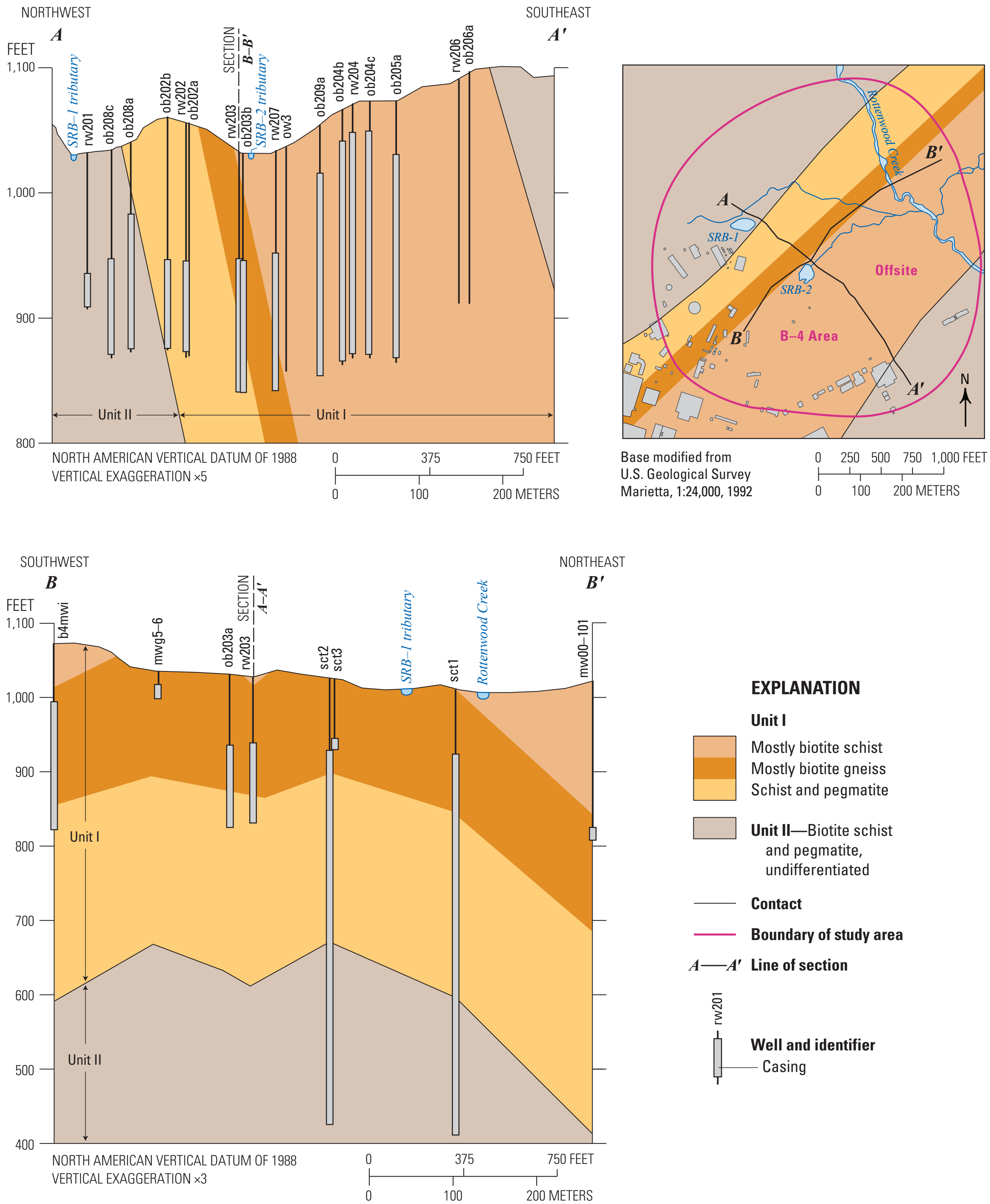


Figure 55. Geologic cross sections and map showing corresponding lines of section (traces). The length of each cross section is double that of each trace on the map. The editor and the cartographer have carefully compared the placement of the geographic and geologic features on the map to those same features on the cross sections and have confirmed that all features are correctly placed. Even though the datum note is the same for each cross section, the vertical exaggeration is different and has been specified.

Geologic cross sections of the B–4 Area, U.S. Air Force Plant 6, Marietta, Ga. Figure modified from Gerard J. Gonthier (USGS, written commun., February 2010).

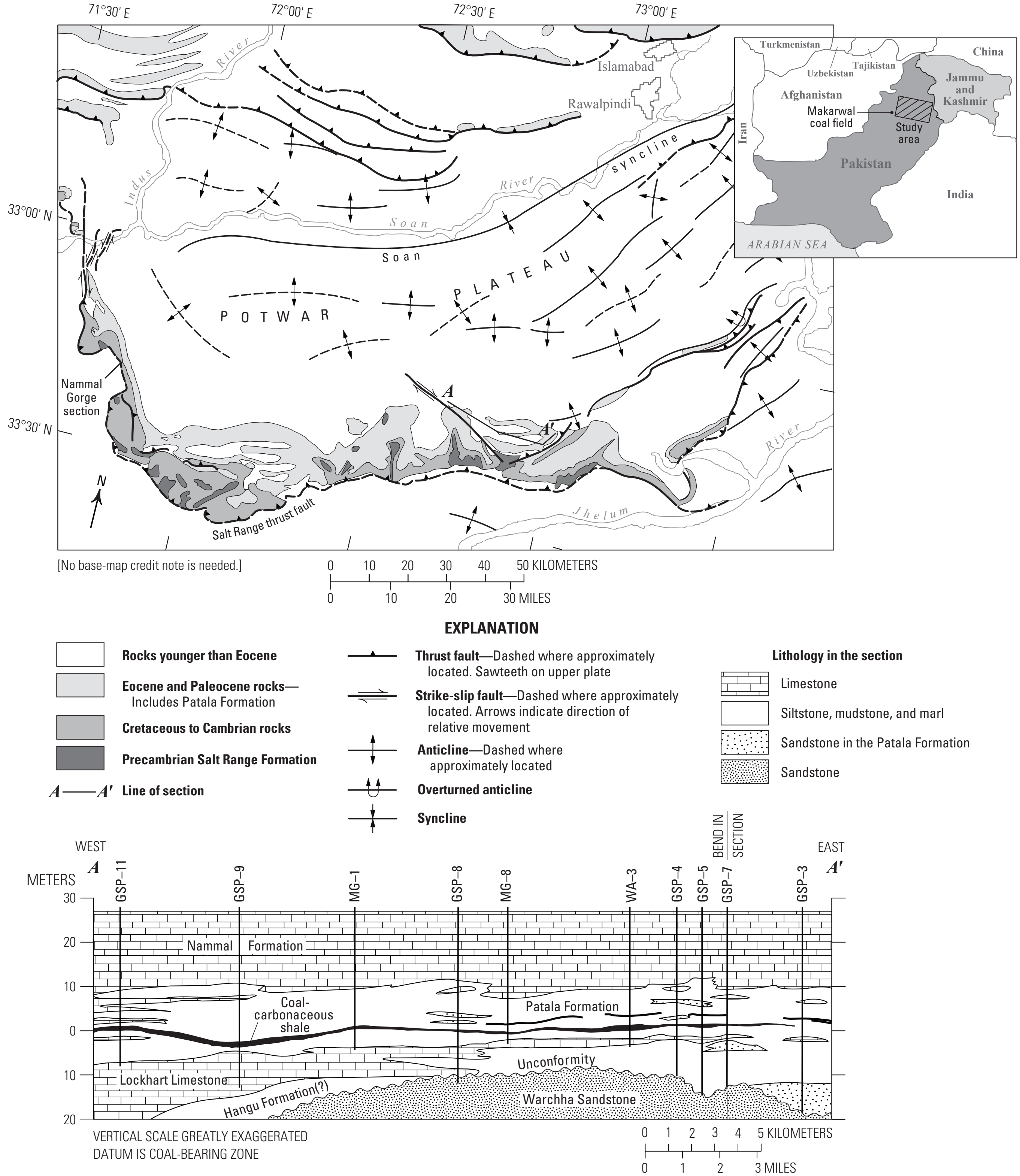
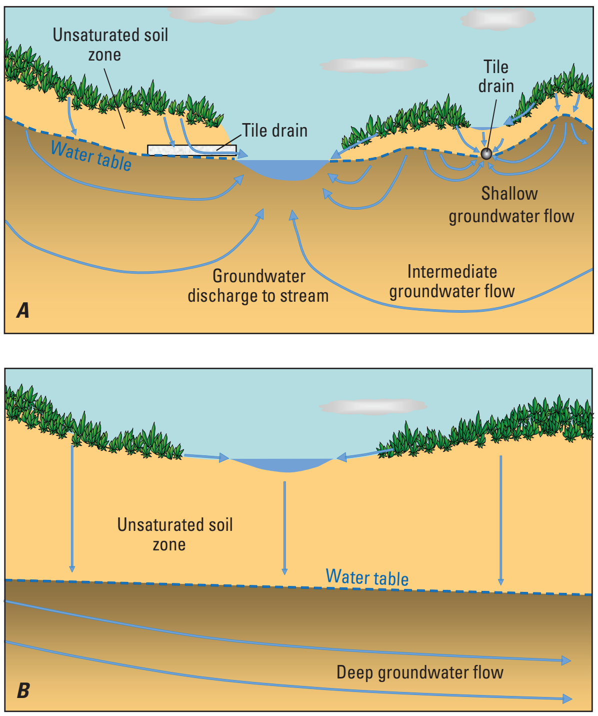


Figure 56. A page-size map, an index map, an explanation, and a cross section, all on one page, all in one figure. Because the map is oriented such that north is not at the top of the page, a latitude-longitude grid and a north arrow are shown. Because the map is generalized, no base-map credit note is needed. In the explanation, the first two columns of information define features on the map above and the last column defines units in the cross section below. The cross section is six times as long as its corresponding trace on the map, an even multiple.

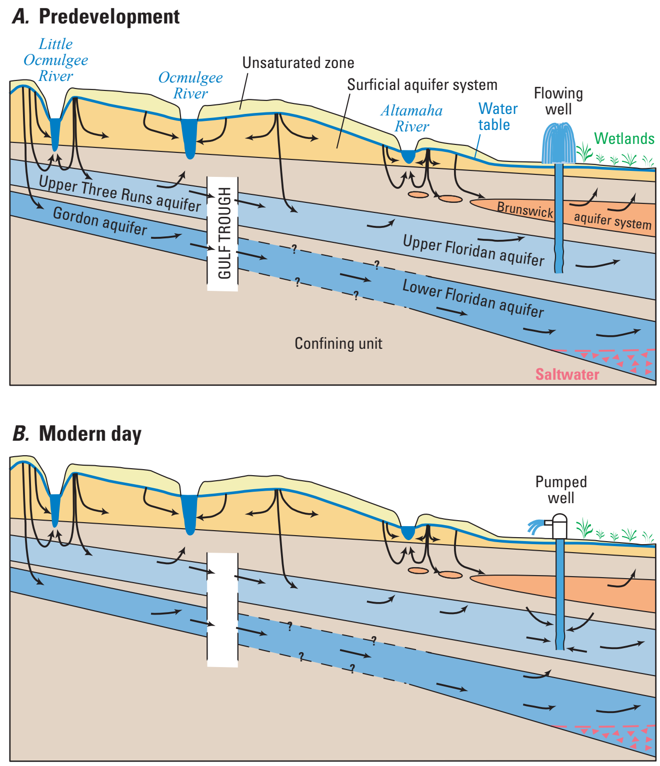
Generalized geologic map of the Salt Range study area, northern Pakistan (modified from Baker and others, 1988), and a detailed section of the coal-bearing and associated rocks in the central part of the Salt Range coal field. Figure modified from Warwick and Shakoor (2007).

Schematic Cross Sections



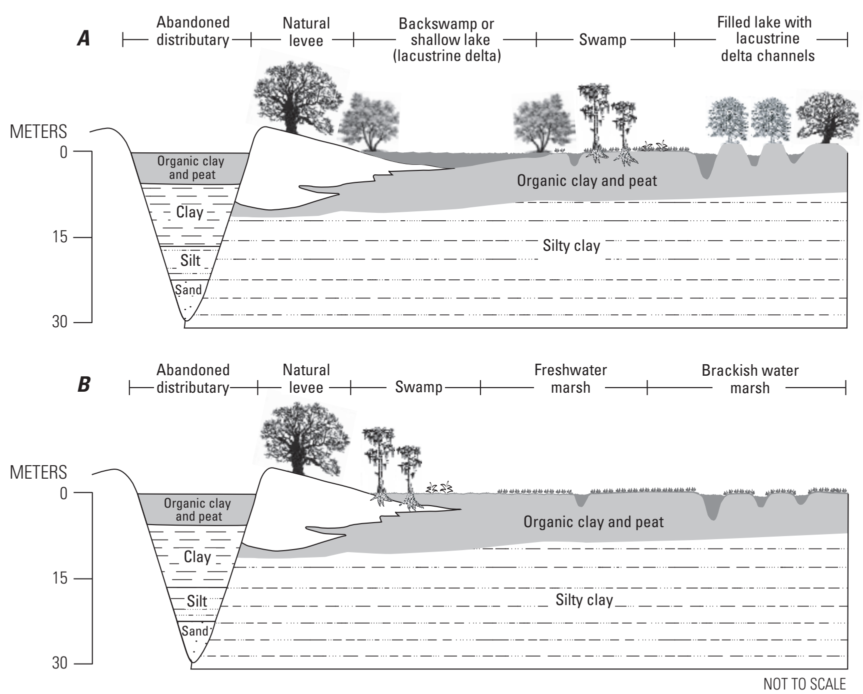
NOT TO SCALE

A, Various relatively short flow paths may connect agricultural fields to streams in areas where the water table is shallow. *B,* Many flow paths from agricultural fields may bypass local streams in areas where the water table is deep. Figure modified from U.S. Geological Survey (2009).



NOT TO SCALE

Schematic diagram showing conceptual model of *(A)* predevelopment and *(B)* modern-day (2000) flow system. Arrows indicate general direction of groundwater flow. Figure modified from Payne and others (2005).



Depositional environments in *(A)* "interior basin" and *(B)* "lower basin" areas of the Mississippi River deltaic plain. Sediments in the interior basin show no evidence of marine influence; lower basin sediments have physical and chemical properties indicative of marine influence. Figure modified from Markewich and others (2007).

Figure 57. Schematic cross sections like the ones shown in this figure give the reader a general idea of what is going on beneath the surface of the land. They are usually based on a scientist's general knowledge of an area or on data that have been collected from a wide area. Placing two cross sections together helps the reader compare different flow systems, different time periods, or different environments. In the two examples at the top of the page, the "not to scale" note refers to both the vertical and horizontal scales. In the example to the right, the "not to scale" note refers only to the horizontal scale.

Sections Created from a Model

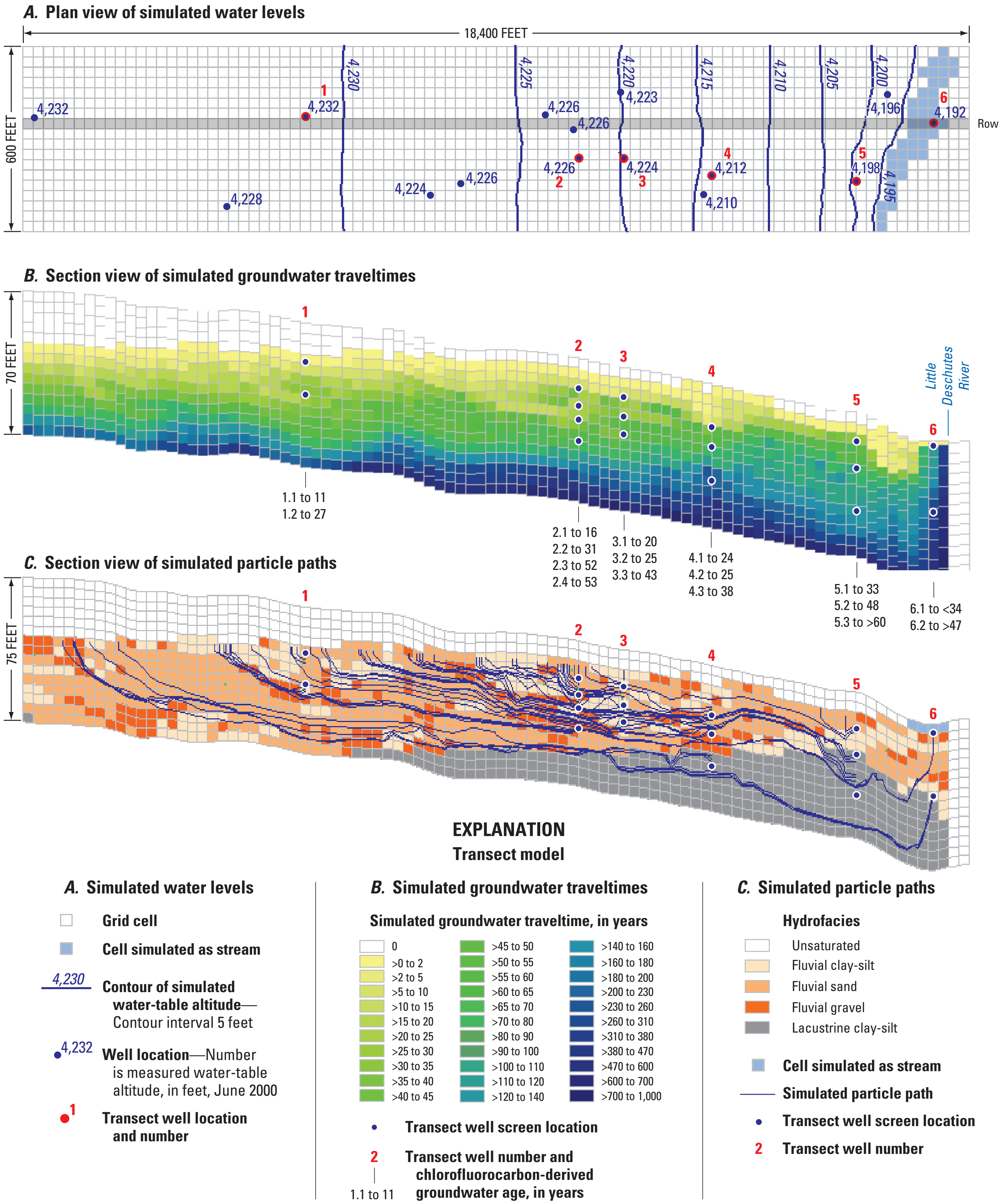


Figure 58. A nontraditional cross section created by using output from a model. “Traveltime” is one word, as per GPO (2008, p.182).

Plan and section views of the transect model showing simulated water levels, groundwater traveltimes, and particle paths in the La Pine, Oregon, study area. Figure modified from Morgan and others (2007).

Hydrologic Sections

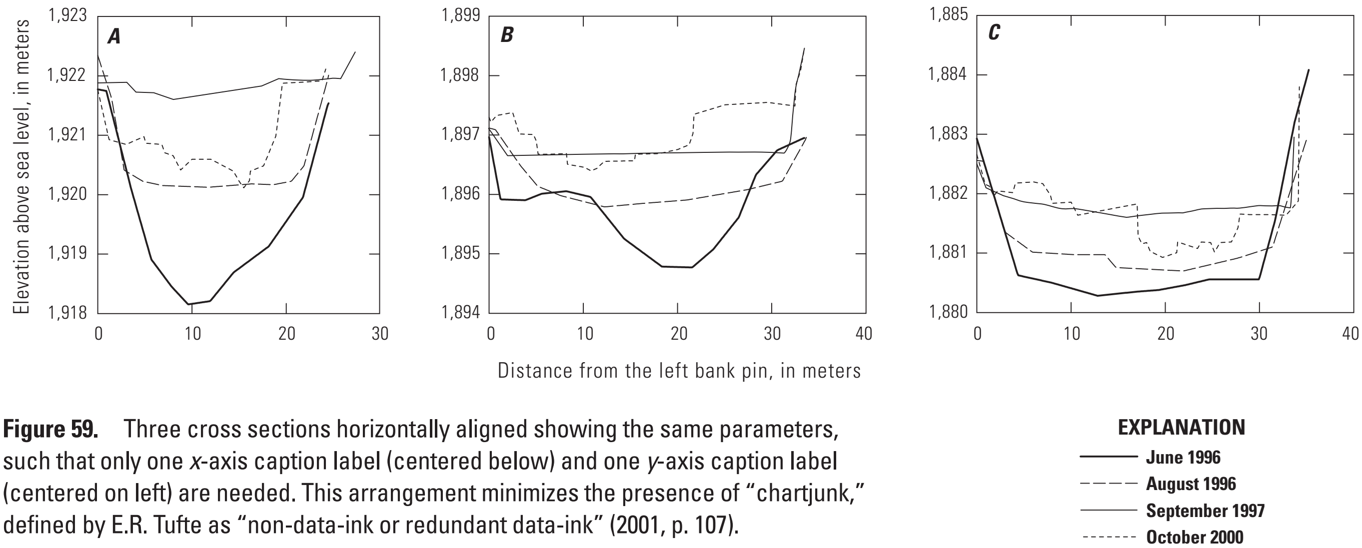


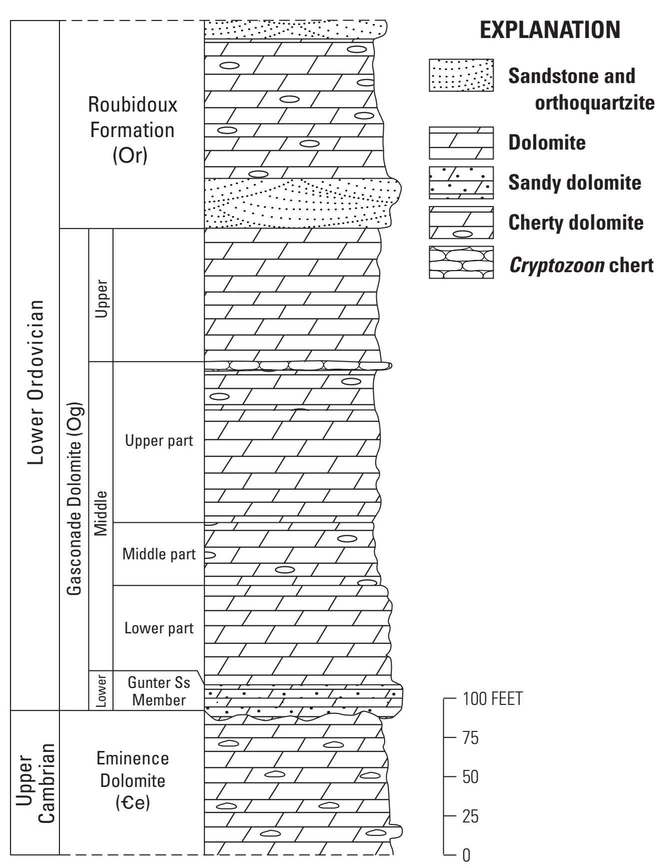
Figure 59. Three cross sections horizontally aligned showing the same parameters, such that only one *x*-axis caption label (centered below) and one *y*-axis caption label (centered on left) are needed. This arrangement minimizes the presence of "chartjunk," defined by E.R. Tufte as "non-data-ink or redundant data-ink" (2001, p. 107).

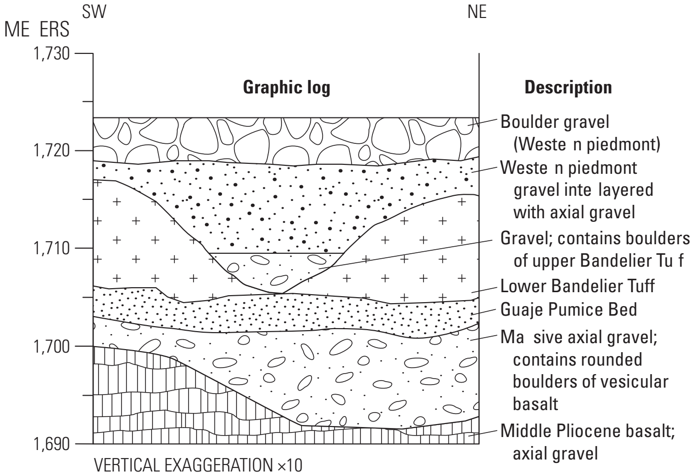
Profiles of Spring Creek, Pike National Forest, southwest of Denver, Colo. Profiles for June 1996 show the creek's morphology after the wildfire but before the erosion caused by intense rainstorms and flooding in June and July 1996. Profiles for August 1996 show the creek's morphology after the erosion in June and July 1996. Profiles for September 1997 show the creek's morphology after the flash flood on August 31, 1997. Profiles for October 2000 show the creek's morphology after a long period with no significant flash floods. Figure modified from Moody and Martin (2001).

Stratigraphic Columnar Sections (Geologic Columns)

Figure 60. Stratigraphic columnar section using lithologic patterns that differ from those in the FGDC Standard because they were chosen before its release in 2006. These same patterns have been used in subsequent columnar sections for a series of 1:24,000-scale quadrangle maps of southeastern Missouri, the first of which was published in 1998. Notice that all text is centered horizontally and vertically within each box. If space permits, spell out all text in figures; however, if abbreviations are necessary because of space constraints, they may be spelled out in the figure caption.

Formations that crop out in the Cedargrove quadrangle, Missouri. Ss, sandstone. Figure modified from Weary (2008).





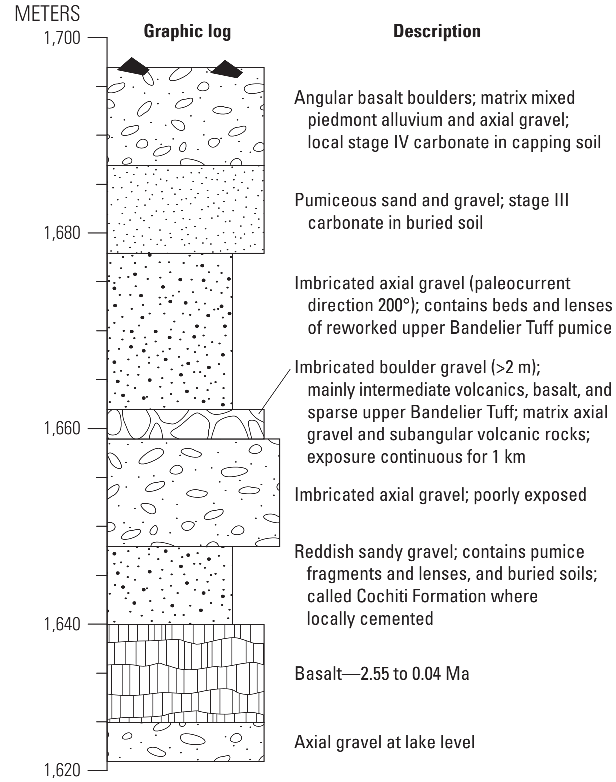
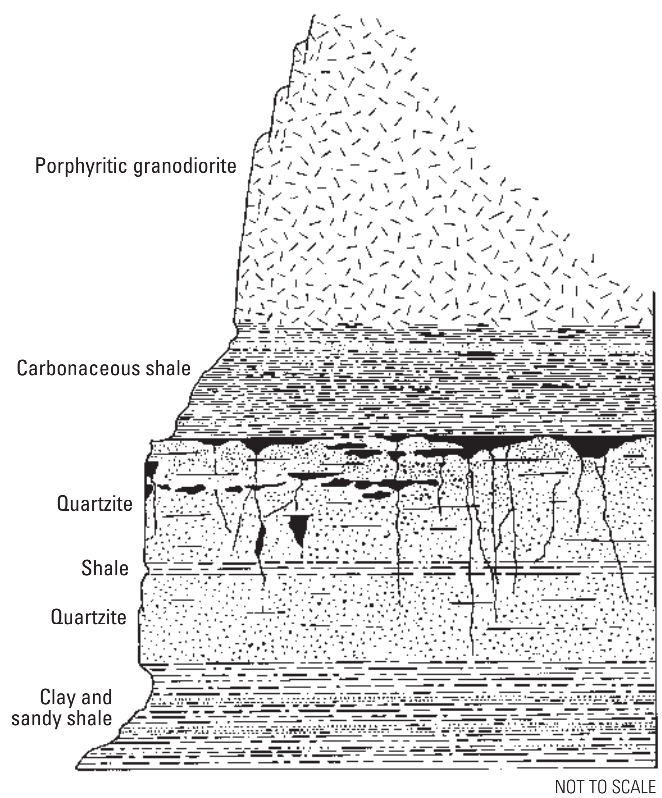


Figure 61. Stratigraphic columnar sections using patterns directly from the FGDC Standard and patterns that were created when none were found in the FGDC Standard. Blocks of descriptive text should be centered vertically on the corresponding polygons of the graphic log. If space is an issue, text may be offset or leaders may be used for clarity. Adjust the length of each line of text so as to avoid "orphans," which are one-word lines of text. Don't forget to indent overruns. Ma, mega-annum.

Graphic logs and descriptions of stratigraphic sections near the Rio Grande River, La Bajada constriction area, New Mexico. Figures modified from Dethier and Sawyer (2006).

Figure 62. Generalized section showing what is meant by "standard outcrop form" for a cliff. This figure also shows hand drawn lithologic patterns whose elements have changed little over the years since this report was originally published in 1905.

Cliff face at the American Nettie mine, Ouray, Colo., showing stratigraphic relations and the ore shoots (dark), or filled solution cavities, formed within the quartzite mostly beneath impervious barriers or partings of shale as suggested by the flat tops (from Irving, 1905, fig. 4).



Block Diagrams and Fence Diagrams

Introduction

A block diagram is “a generalized representation of a four-cornered portion of the landscape, shown in perspective or isometric projection, usually with some vertical exaggeration, often used to show structures hidden beneath the surface” (Reitz, 2010). A block diagram can depict geologic, hydrologic, and topographic features and is aimed more at presenting an overall view, rather than a detailed analysis, of a particular area. The top of the block diagram gives a bird’s-eye view of the land surface, and the two sides show what is buried underneath.

Shown in this section are traditional block diagrams (p. 112 and 113); “exploded” block diagrams, where the land surface on the top of the block has been “lifted up” to show underlying features or structures (p. 114); and “cutaway” block diagrams, where the front face of the block has been cut away to show internal features or structures (p. 115). All of these block diagrams were created in one of three ways: (1) by using a combination of traditional (hand drawn) and digital (Adobe Illustrator) techniques; (2) by using Adobe Illustrator; or (3) by using mainly Adobe Photoshop (p. 116 and 117).

Appropriate placement of text on the top and faces of a block may be tricky as the text needs to be skewed and (or) rotated to look like it is laying on the top of the block or along the plane of the faces. The experience and judgment of the illustrator are needed to give block diagrams a professional look.

A fence diagram is a drawing in perspective of three or more geologic sections, showing their relations to one another. Shown are three “traditional” fence diagrams and one fence-diagram-like figure (p. 118–121).

Appropriate placement of text on the top and faces of a block may be tricky as the text needs to be skewed and (or) rotated to look like it is laying on the top of the block or along the plane of the faces. The experience and judgment of the illustrator are needed to give block diagrams a professional look.

Examples of Block Diagrams

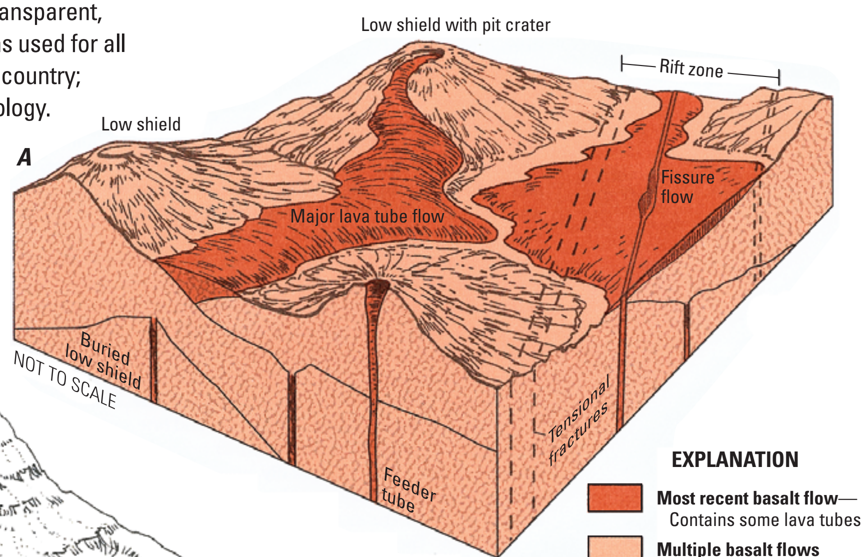
Block Diagrams Created by Using Traditional and Digital Methods

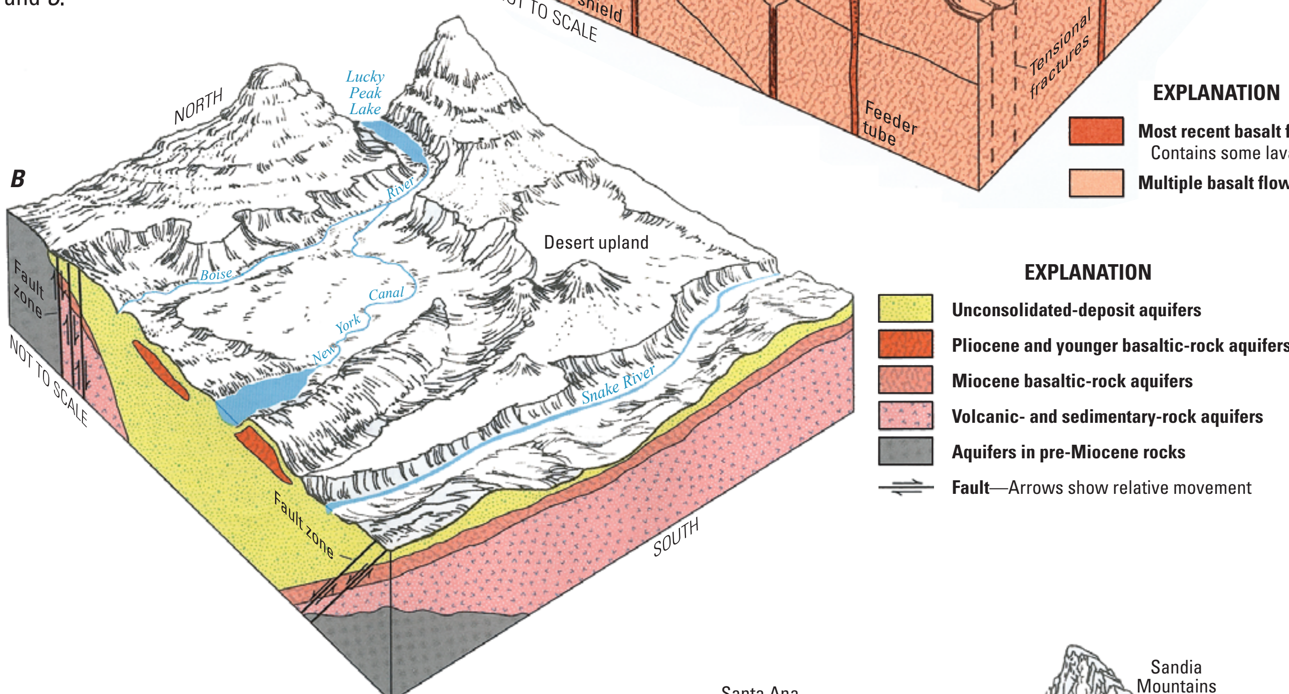
Figure 63. Three block diagrams from individually authored chapters C and H of the Ground Water Atlas of the United States (U.S. Geological Survey, 2000). All were created in the same fashion. The original artwork was hand drawn and then the sketches were scanned. Linework below surface level was redrawn by using Adobe Illustrator (AI). Color fills also were created by using AI, and the scanned surfaces of the blocks were made transparent, screened, and placed in the AI file. Colors and patterns used for all aquifers were part of a scheme created for the entire country; the color indicated age, and the pattern indicated lithology. Note how the use of linework shows the intricacies of the landscape. In addition, the type on the block faces is skewed in order to give the impression that it is set in the plane of the block face. The complete original AI files could not be obtained, so these images have been scanned. As a result, moiré patterns are evident, especially in the gray color fill of *B* and *C*.

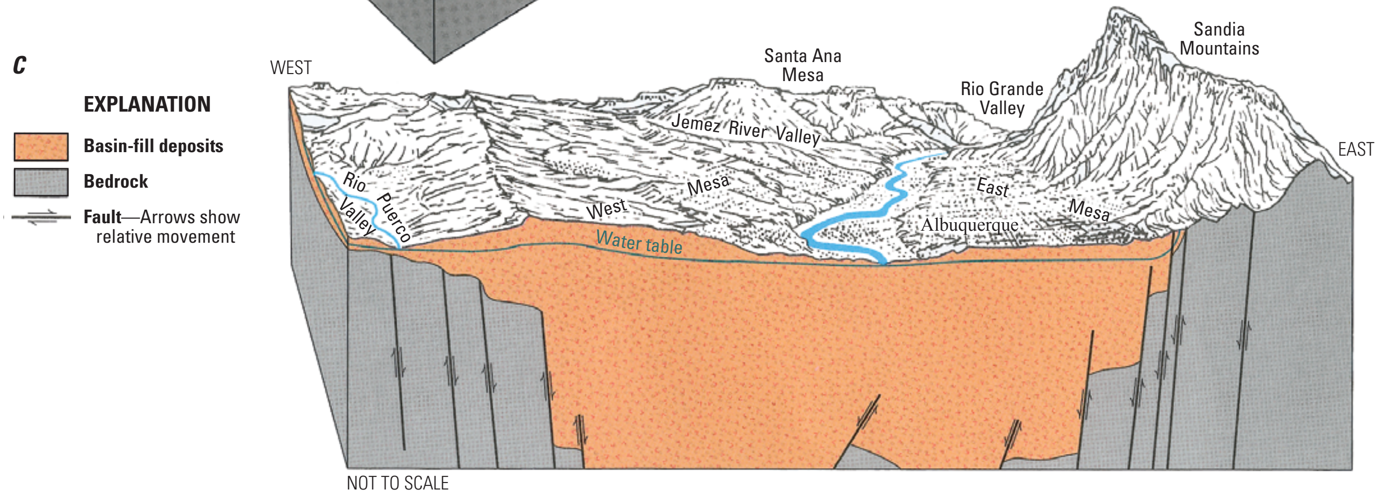
A, Basaltic lava flows characteristic of Pliocene and younger basaltic-rock aquifers. Figure modified from Whitehead (1994, chap. H, fig. 27).

B, Unconsolidated-deposit aquifers in the western Snake River Plain. Figure modified from Whitehead (1994, chap. H, fig. 65).

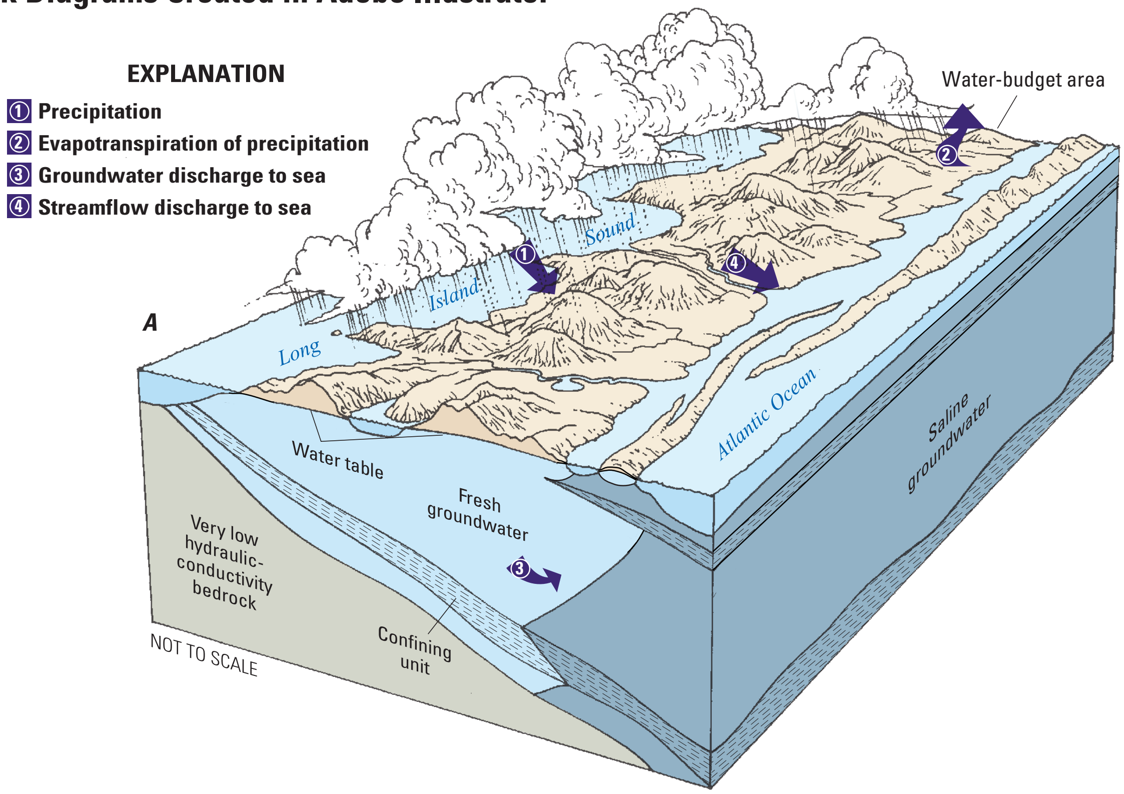
C, Land surface and its relation to generalized subsurface geology near Albuquerque, N. Mex. Figure modified from Robson and Banta (1995, chap. C, fig. 56).







Block Diagrams Created in Adobe Illustrator



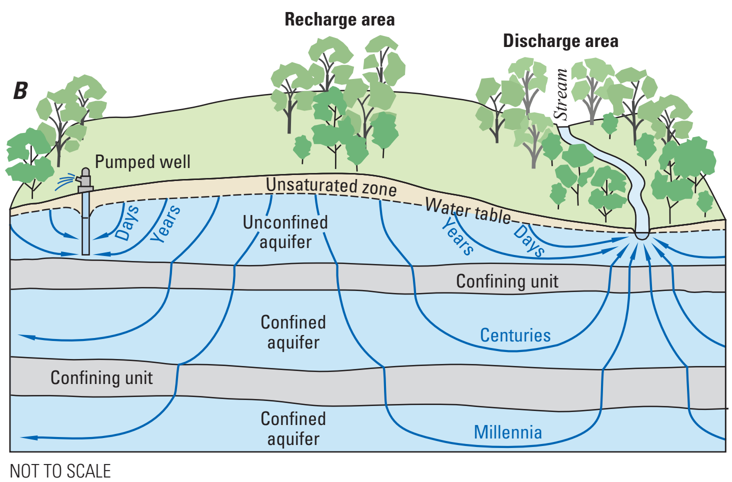
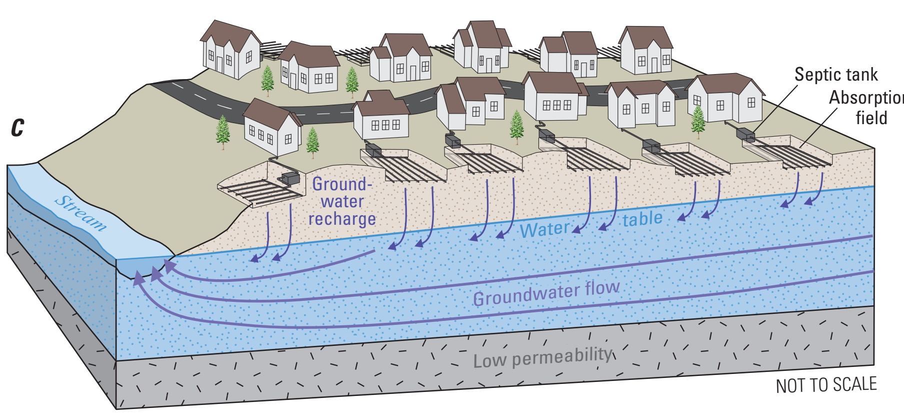


Figure 64. Three block diagrams that could easily be created entirely in Adobe Illustrator.

A, Some components of the groundwater budget, predevelopment, for part of Nassau and Suffolk Counties, Long Island, N.Y. Figure modified from Alley and others (1999).

B, Areal extent and thickness of unconfined and confined aquifers, the length and traveltime of groundwater flow paths, and the thickness of the unsaturated zone vary locally as well as regionally. Figure modified from Winter and others (1998).

C, Conceptual diagram of groundwater recharge and increased base flow from onsite septic wastewater-treatment systems. Figure modified from Landers and Ankcorn (2008).

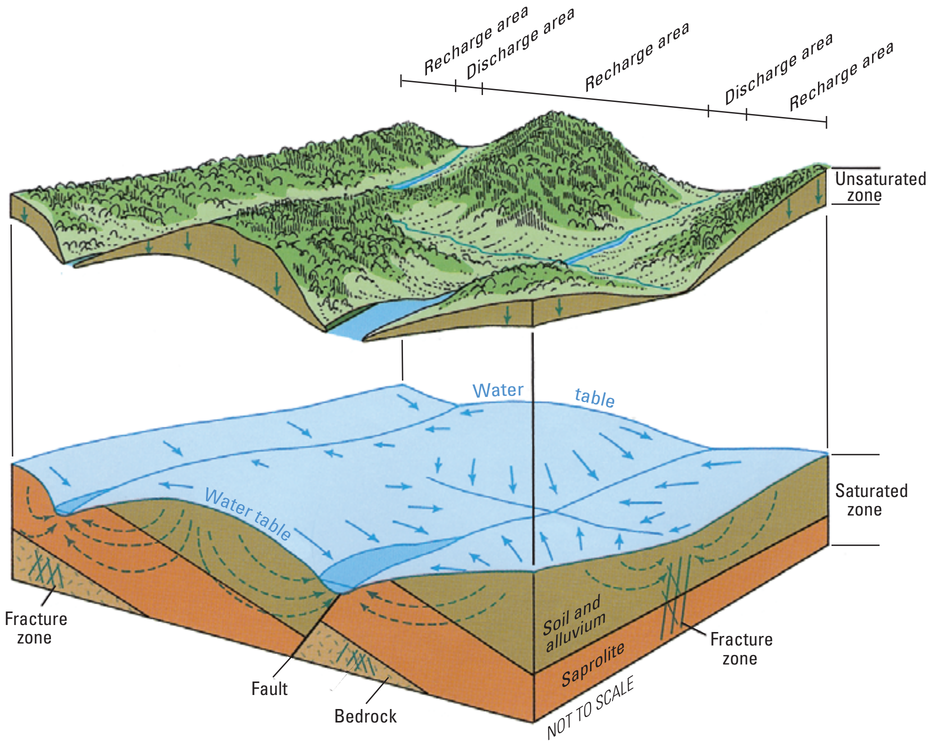


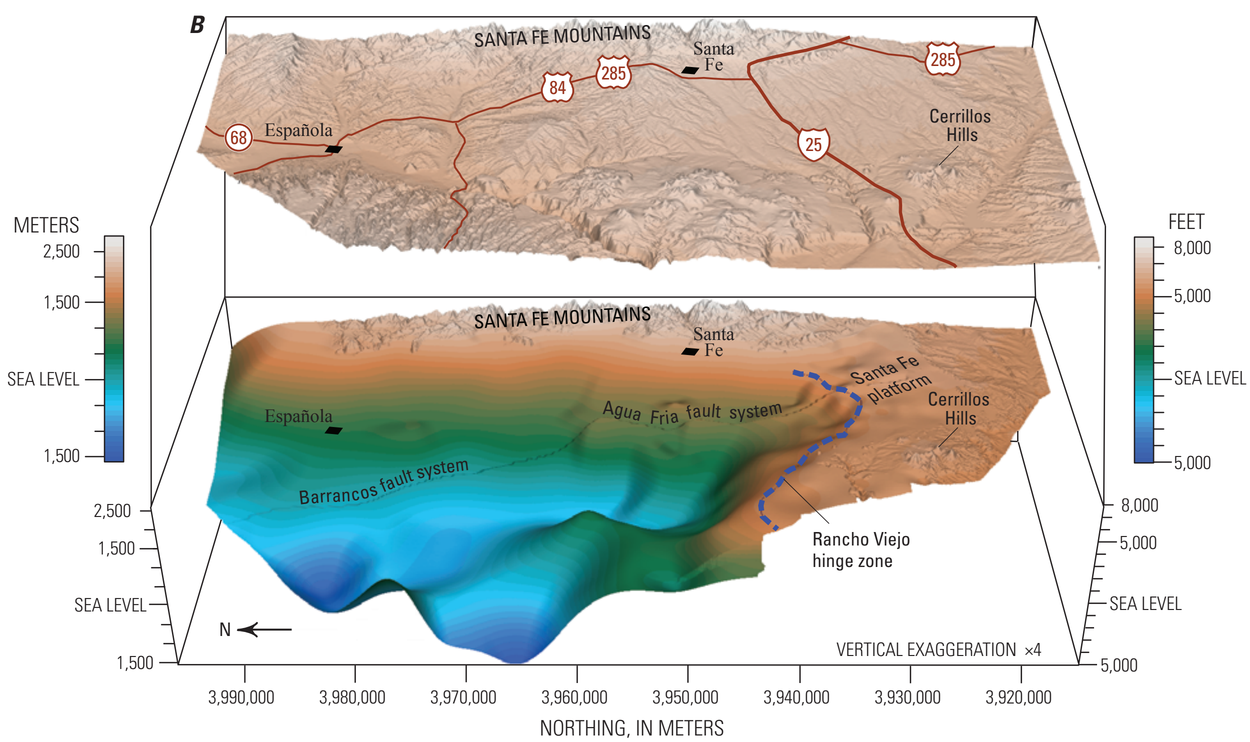
“Exploded” Block Diagrams

Figure 65. “Exploded” block diagrams allow the reader to see both the land surface and the area directly underneath at the same time. Do not use minus signs for values below sea level; they can be confused with ticks. Also, geology and water reports handle use of the term “sea level” differently.

A, Groundwater percolates downward through the unsaturated zone (shown lifted up) to the water table, then moves laterally through the saturated zone to discharge points. In bedrock, water is channeled through fracture zones. Arrows show direction of groundwater flow. Figure modified from Miller (1990, fig. 92).

B, Perspective view of the modeled base of the Santa Fe Group in relation to topography, southern Española Basin, N. Mex. Figure modified from Grauch and others (2009).



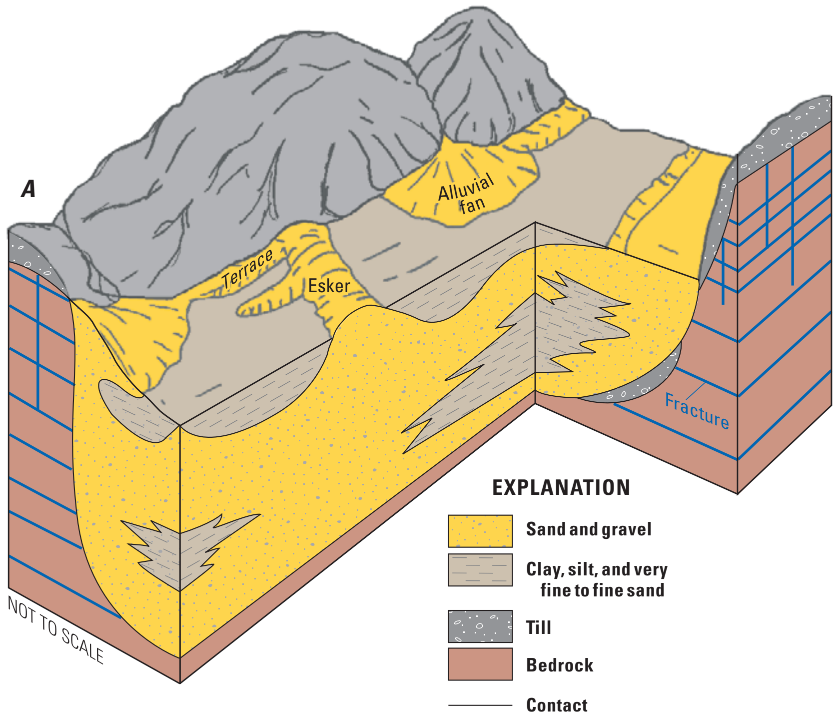


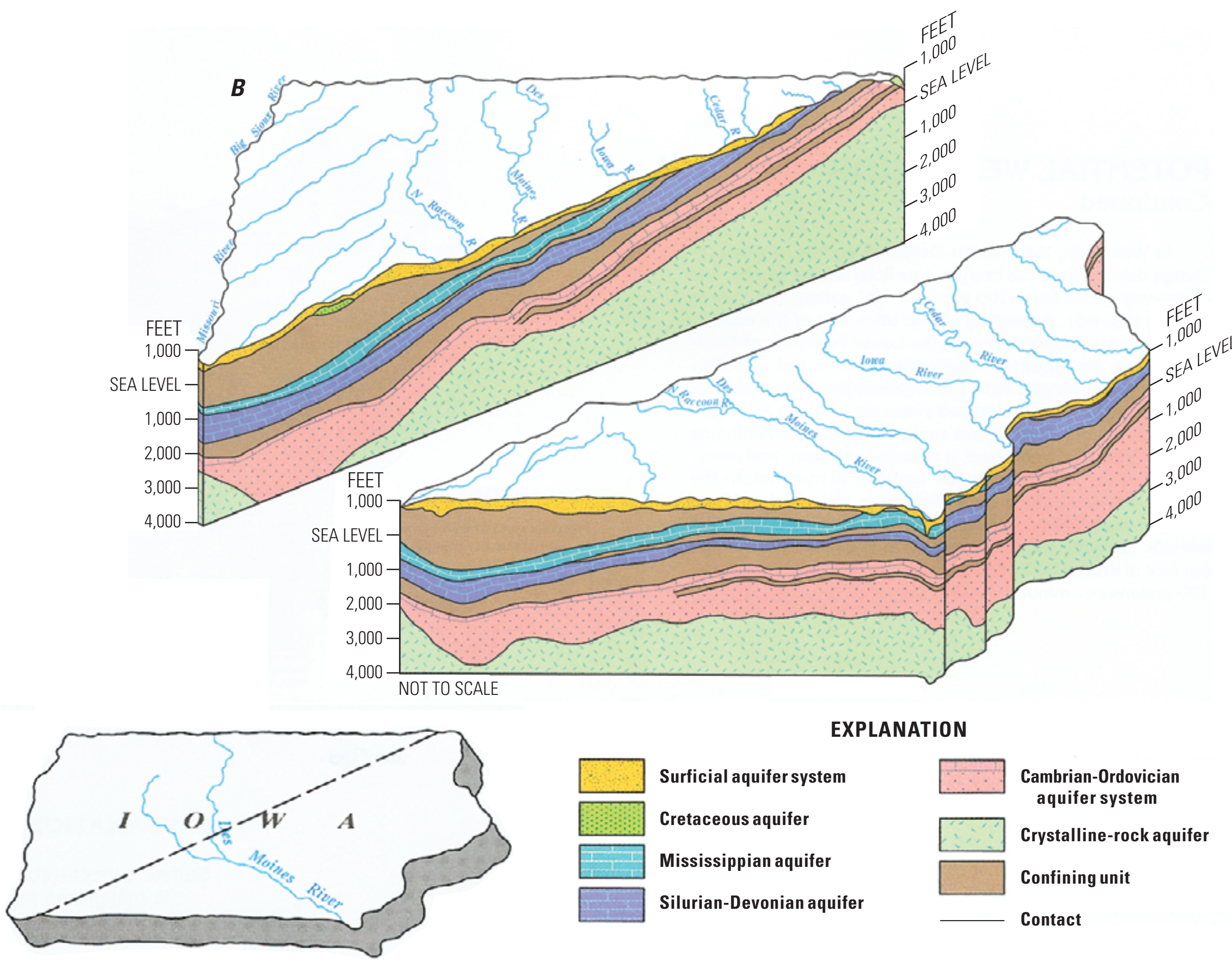
"Cutaway" Block Diagrams

Figure 66. "Cutaway" block diagrams where the front face of the block is cut and "removed" so that a view of the inner part of the block may be seen or the block is cut and "pulled apart" so that an inner slice of the block may be seen.

A, Valley-fill glacial aquifers, like the Corning aquifer, were deposited by meltwater streams that drained away from the stagnating and melting glacial ice. Terraces, eskers, and alluvial fans are common surface features on the valley floor. Figure modified from Olcott (1995, fig. 25).

B, The Silurian-Devonian aquifer dips southwestward in Iowa from the area where the aquifer forms the bedrock surface in the northeast to areas where it is deeply buried in the southwest. Figure modified from Olcott (1992, fig. 80).





Block Diagrams Created Mainly in Adobe Photoshop

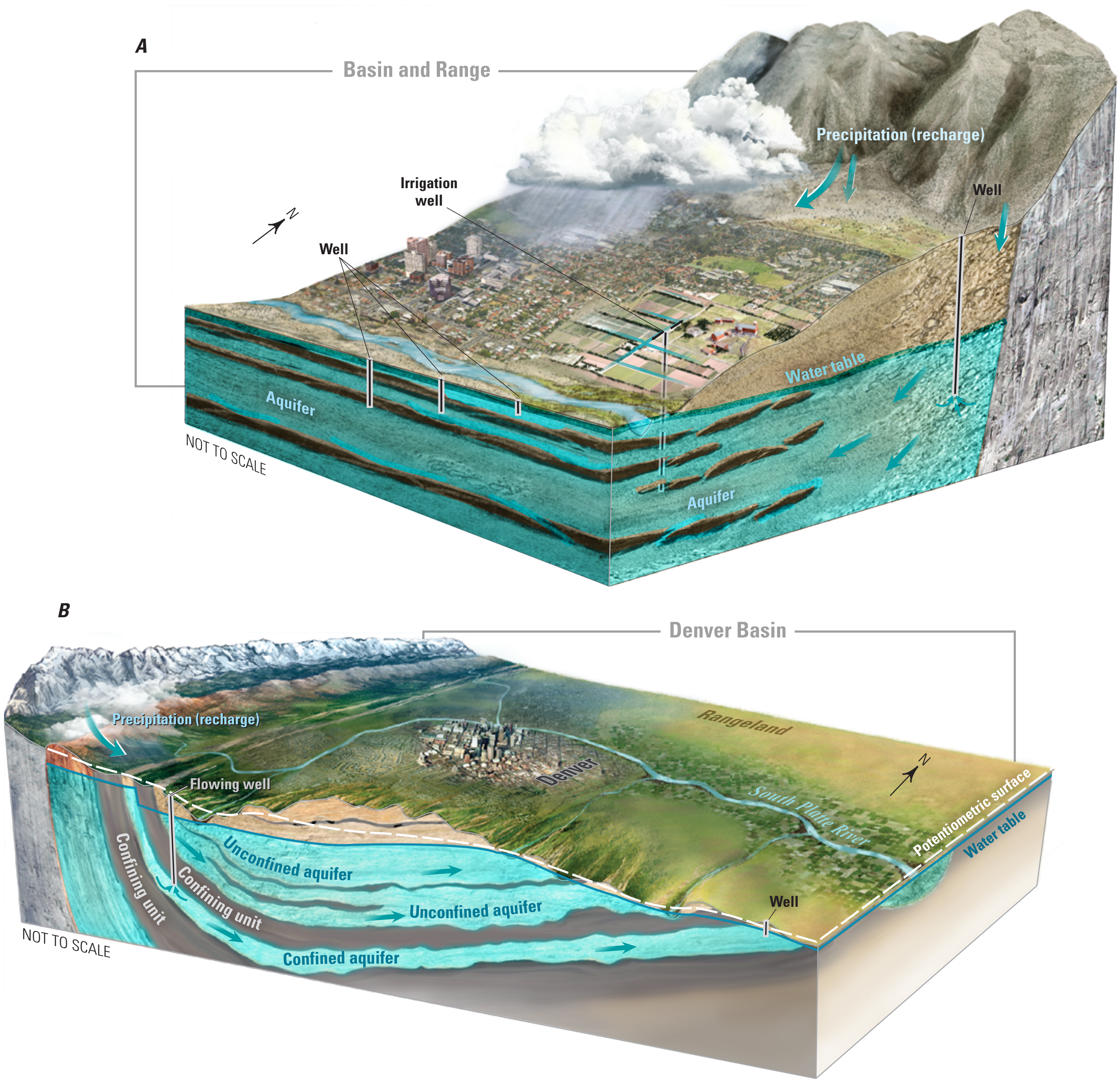


Figure 67. Schematic block diagrams showing different geohydrologic settings. Black and white line drawings of the geology were created in Adobe Illustrator and were used as a guide to create the diagrams, but much of the finishing work was done in Adobe Photoshop. Subsurface geologic features (represented by gray-colored rock and tan-colored sediment, for example) were created from photographs that were modified using filters found in Adobe Photoshop. Mountains, clouds, forests, and gravel were rendered using Adobe Photoshop scatter brushes. All brushwork was done with the aid of a graphics tablet.

Urban and rural features were created using photographs and three-dimensional models available free via download from Google Sketchup™. The jpeg (.jpg) files of these features were placed into the illustrations, appropriately angled, and then integrated using Adobe Photoshop brushes and layer settings. To create a sense of depth and enhance the three-dimensional feel, color gradients were overlaid on the images, and features in the distance were sometimes blurred. Water saturation zones were created using gradients, effects, and transparencies. Labels and water features (such as aquifers and water table) were added using Adobe Illustrator.

A, Figure modified from Susan A. Thiros (USGS, written commun., July 2010). *B*, Figure modified from Suzanne Paschke (USGS, written commun., July 2010).

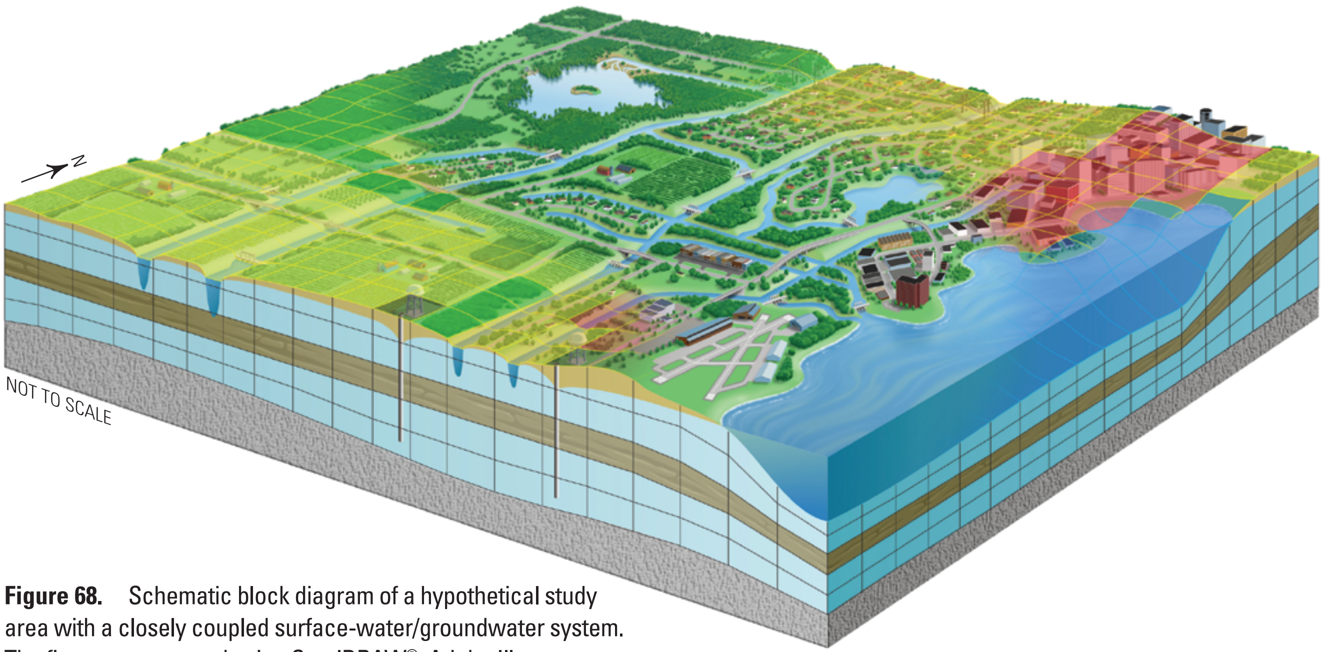


Figure 68. Schematic block diagram of a hypothetical study area with a closely coupled surface-water/groundwater system. The figure was created using CorelDRAW®, Adobe Illustrator, and Adobe Photoshop. By far the majority of the work was done in Adobe Photoshop, and the final file has 28 layers. The figure was constructed such that individual surface features can be selectively removed as needed to either emphasize other surface features or to reduce clutter.

Surface-water system and associated control structures (dams, canals, and so forth), land use-land cover, and aquifers and confining units under the study area. This illustration was prepared as part of a Techniques and Methods report documenting a MODFLOW 2005 surface-water-routing package. The yellow-colored grid on the surface at the southwestern and northeastern corners of the block represents a numerical model grid. Figure modified from Joseph D. Hughes (USGS, written commun., February 2010).

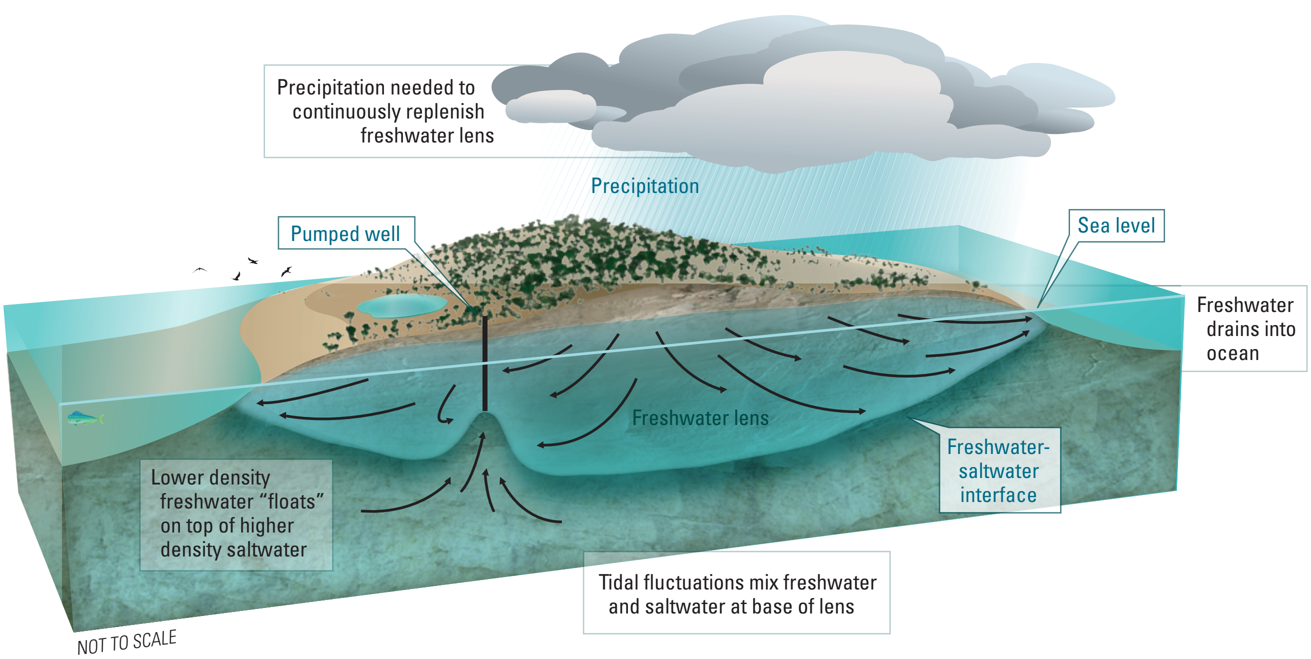


Figure 69. Schematic block diagram of a groundwater lens cycle. Note that the labels identifying specific features are shown in blue, and the explanatory text (explaining the groundwater lens cycle) is shown in black. Arrows are used only to indicate direction—not as leaders. Also note the addition of island vegetation, a fish, and a colony of seagulls.

Andros, Bahamas, freshwater lens showing how the lens is saturated throughout the island and how the lens is affected by a pumped well and the surrounding ocean. Illustration prepared as part of a PowerPoint presentation and could easily be formatted for inclusion in a formal-series report. Figure modified from Bret Bruce (USGS, written commun., October 2009).

Examples of Fence Diagrams

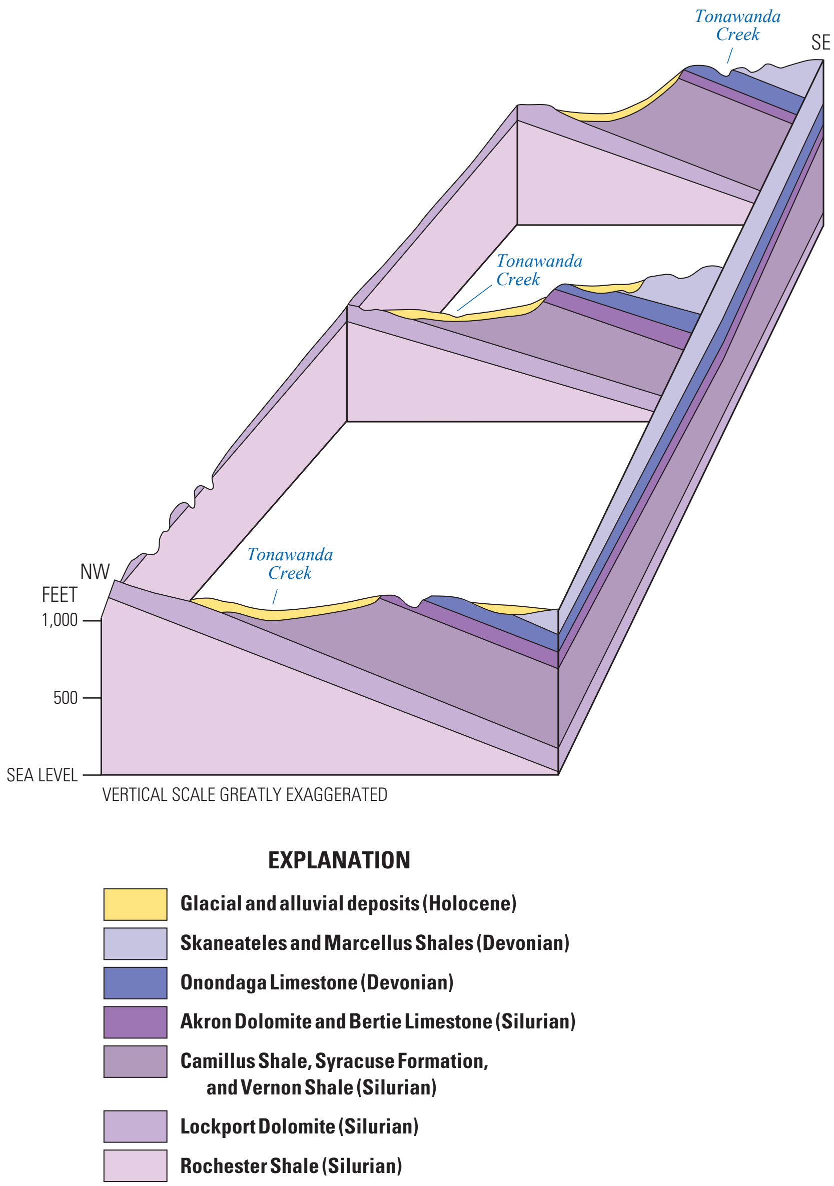


Figure 70. An example of a classic fence diagram, which Jackson defines as "a drawing in perspective of three of more geologic sections, showing their relationships [sic] to one another" (1997, p. 231).

Bedrock geologic units of marine origin in the Lake Erie-Niagara River Basin, New York. The units are Silurian and Devonian in age and are virtually flat lying, with a gentle dip to the south of about 30 to 40 feet per mile. Figure modified from Olcott (1995, fig. 88).

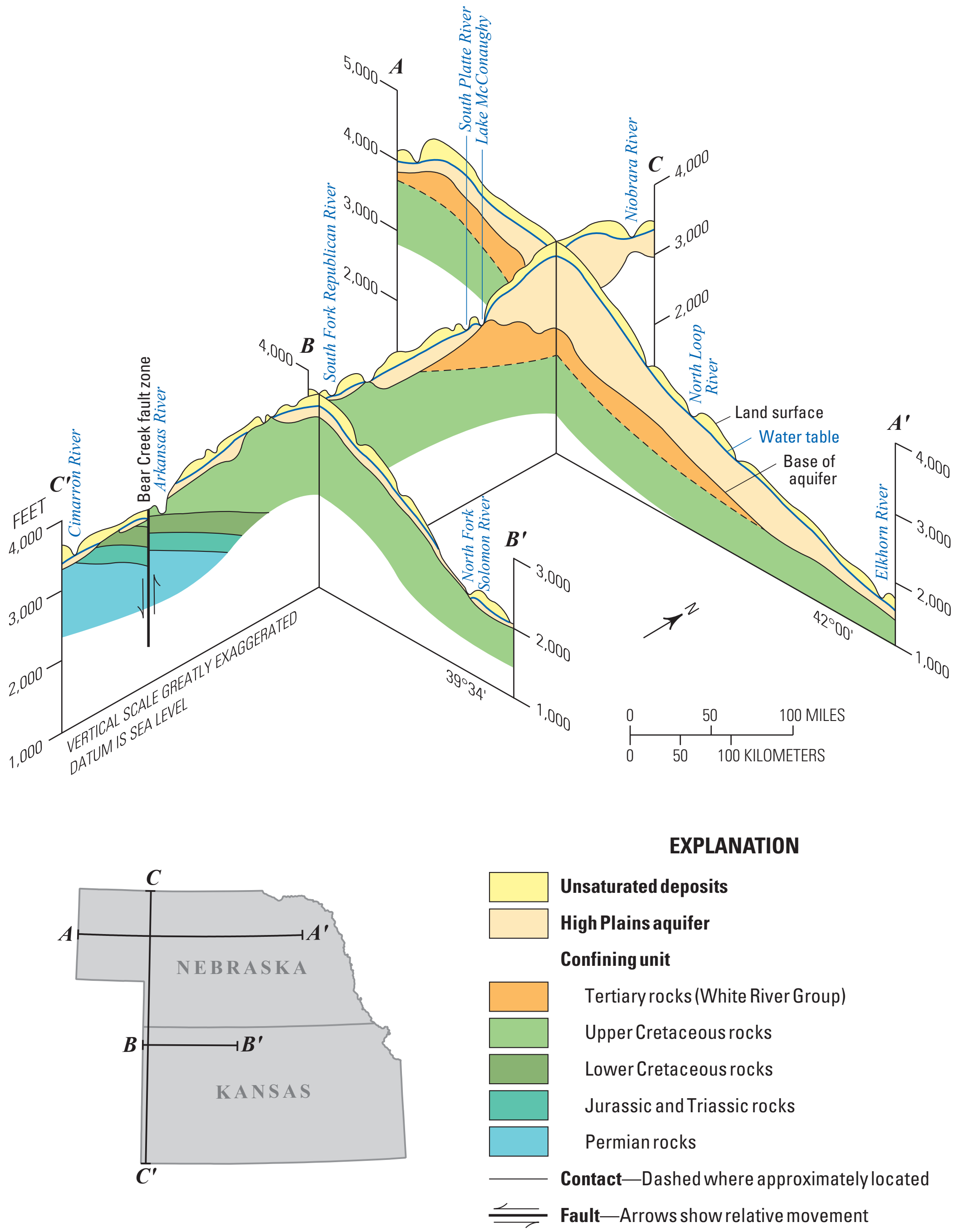


Figure 71. Fence diagram and location map showing lines of section. Both vertical and horizontal scales are shown in the fence diagram. Note: A scratch boundary (no bounding line and white to the base of the diagram) defines the lowermost extent of the portrayed geology.

The High Plains aquifer is as much as 1,000 feet thick in north-central Nebraska but thins to the south and east. The aquifer overlies rocks of Late Cretaceous age in Kansas, where it generally is less than 250 feet thick. Figure modified from Miller and Appel (1997, fig. 50).

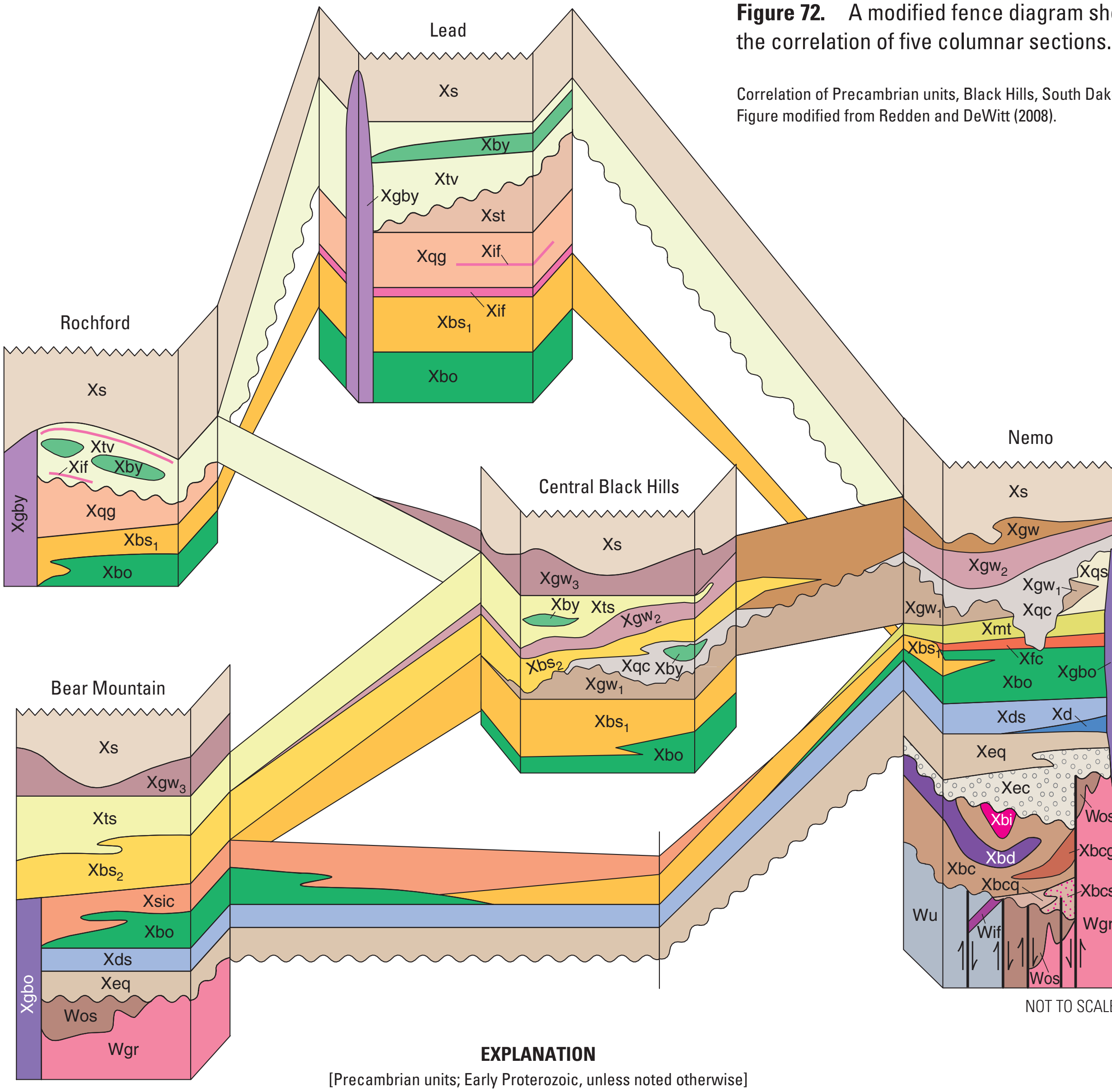


Figure 72. A modified fence diagram showing the correlation of five columnar sections.

Correlation of Precambrian units, Black Hills, South Dakota. Figure modified from Redden and DeWitt (2008).

EXPLANATION

[Precambrian units; Early Proterozoic, unless noted otherwise]

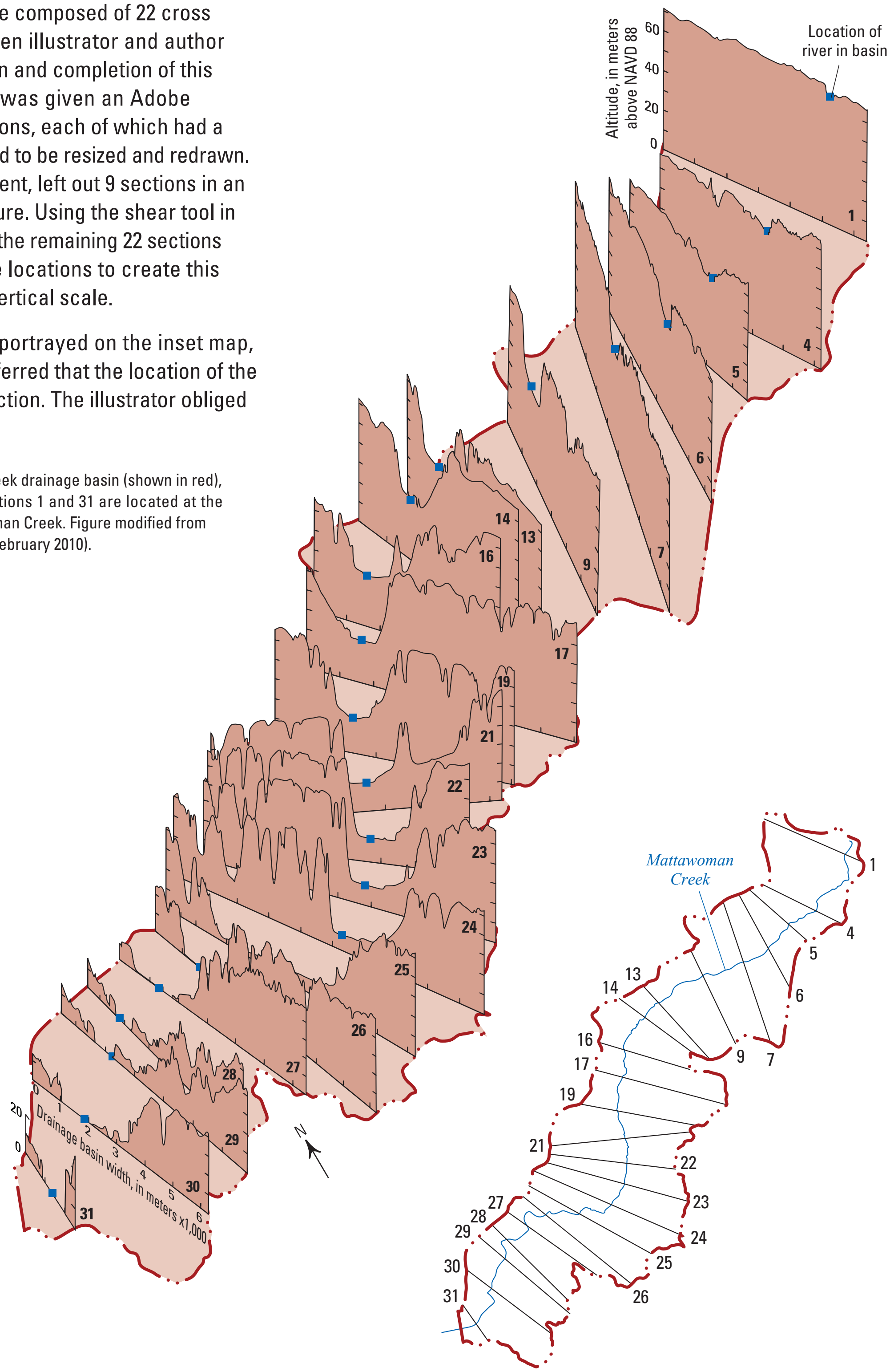
- Xs — Metamorphosed shale
- Xgby — Younger metagabbro
- Xgw — Metagraywacke
- Xgw3 — Metagraywacke unit 3
- Xif — Metamorphosed carbonate-facies iron-formation
- Xby — Metamorphosed younger alkalic basalt, tuff, and volcaniclastic rocks
- Xtv — Metamorphosed tuffaceous shale, tuff, and volcaniclastic rocks
- Xts — Metamorphosed tuff and shale
- Xgw2 — Metagraywacke unit 2
- Xbs2 — Metamorphosed black shale
- Xqc — Metamorphosed quartzite, debris-flow conglomerate, pelite, and graywacke
- Xst — Metamorphosed shale and tuff
- Xgw1 — Metagraywacke unit 1
- Xgbo — Older metagabbro
- Xqg — Metamorphosed quartzite, pelite, and graywacke
- Xqs — Metamorphosed quartzite and pelite
- Xmt — Metamorphosed impure mafic tuff
- Xsic — Metamorphosed shale, siltstone, carbonate-facies iron-formation, and chert
- Xfc — Metamorphosed ferruginous chert
- Xbs1 — Metamorphosed black shale
- Xbo — Metamorphosed older basaltic rocks
- Xds — Metamorphosed dolomite and silty pelite
- Xd — Metamorphosed dolomite
- Xeq — Quartzite
- Xec — Metamorphosed conglomerate and quartzite
- Xbd — Blue Draw Metagabbro
- Xbi — Benchmark Iron-formation
- Boxelder Creek Formation
  - Xbc — Quartzite
  - Xbcg — Metagrit and iron-stained metaconglomerate
  - Xbcs — Chloritic biotite phyllite
  - Xbcq — Impure chlorite quartzite and metaconglomerate
- Wif — Iron-formation (Late Archean?)
- Wu — Late Archean rocks, undivided
- Wos — Older metasedimentary rocks (Late Archean)
- Wgr — Granite (Late Archean)
- Fault—Arrows indicate relative displacement

Fence-Diagram-Like Figure

Figure 73. Fence-diagram-like figure composed of 22 cross sections. Close collaboration between illustrator and author figured prominently in the preparation and completion of this complex illustration. The illustrator was given an Adobe Illustrator (AI) file containing 31 sections, each of which had a slightly different scale. All sections had to be resized and redrawn. The illustrator, with the author's consent, left out 9 sections in an effort to reduce congestion in the figure. Using the shear tool in AI, the illustrator skewed and rotated the remaining 22 sections across the basin at their appropriate locations to create this figure, all the while maintaining the vertical scale.

The continuous trace of the river is portrayed on the inset map, but in the figure itself, the author preferred that the location of the river be shown on each individual section. The illustrator obliged and added the blue rectangles.

Topographic sections across the Mattawoman Creek drainage basin (shown in red), Prince George's and Charles Counties, Md. Sections 1 and 31 are located at the headwaters and mouth, respectively, of Mattawoman Creek. Figure modified from Helaine W. Markewich (USGS, written commun., February 2010).



Miscellaneous

Introduction

This final section includes both general design concepts and layout ideas as well as examples of "non-typical" types of illustrations (not graphs or maps) that might be requested for more outreach-type products, including fact sheets and circulars.

Leading off this section are two figures that show maximum illustration sizes for (1) single-column and double-column figures that have a portrait (bottom-title) orientation and (2) a full-page figure that has a landscape (sidetitle) orientation.

On page 126, guidance is given as to how to lay out and label multipart figures. In addition, an example of a multipart figure is shown (fig. 76). This figure shows a photograph with a few carefully placed labels. Adjacent to the photograph is a sketch with carefully rendered lines and patterns interpreting what is shown in the photograph.

How do you show a "zooming-in" figure effectively? Check out page 127 to see how this is done with a shaded-relief map, a columnar section, and a graph.

A discussion of figure-ground organization is on page 128. This is an important concept that is used when creating a variety of illustrations from graphs (boxplots) to maps (land versus water).

An example of three illustrations using a coordinated color palette follows. Consider using a coordinated color palette in a short publication when you want to quickly engage the reader and tie multiple, interrelated figures together.

Non-typical types of illustrations include schematic diagrams, which are lovely in their subtlety, illustrating at a glance a complicated concept. Schematic diagrams, with their use of bright, bold colors, draw the reader in (see pages 130 and 131).

The four pages of creative illustrations shown at the end of this section (p. 132–135) demonstrate that elements of standards and style are useful when putting together complex and unique illustrations. Use your discretion and good judgment while letting your imagination run wild. Remember to adhere to any specifications that might apply (for example, type, table 1; lineweights, table 4; and symbols, table 6).

Elements of standards and style are still useful when putting together complex and unique illustrations. Use your discretion and good judgment while letting your imagination run wild. Remember to adhere to any specifications that might apply.

Dimensions for Page-Size Illustrations

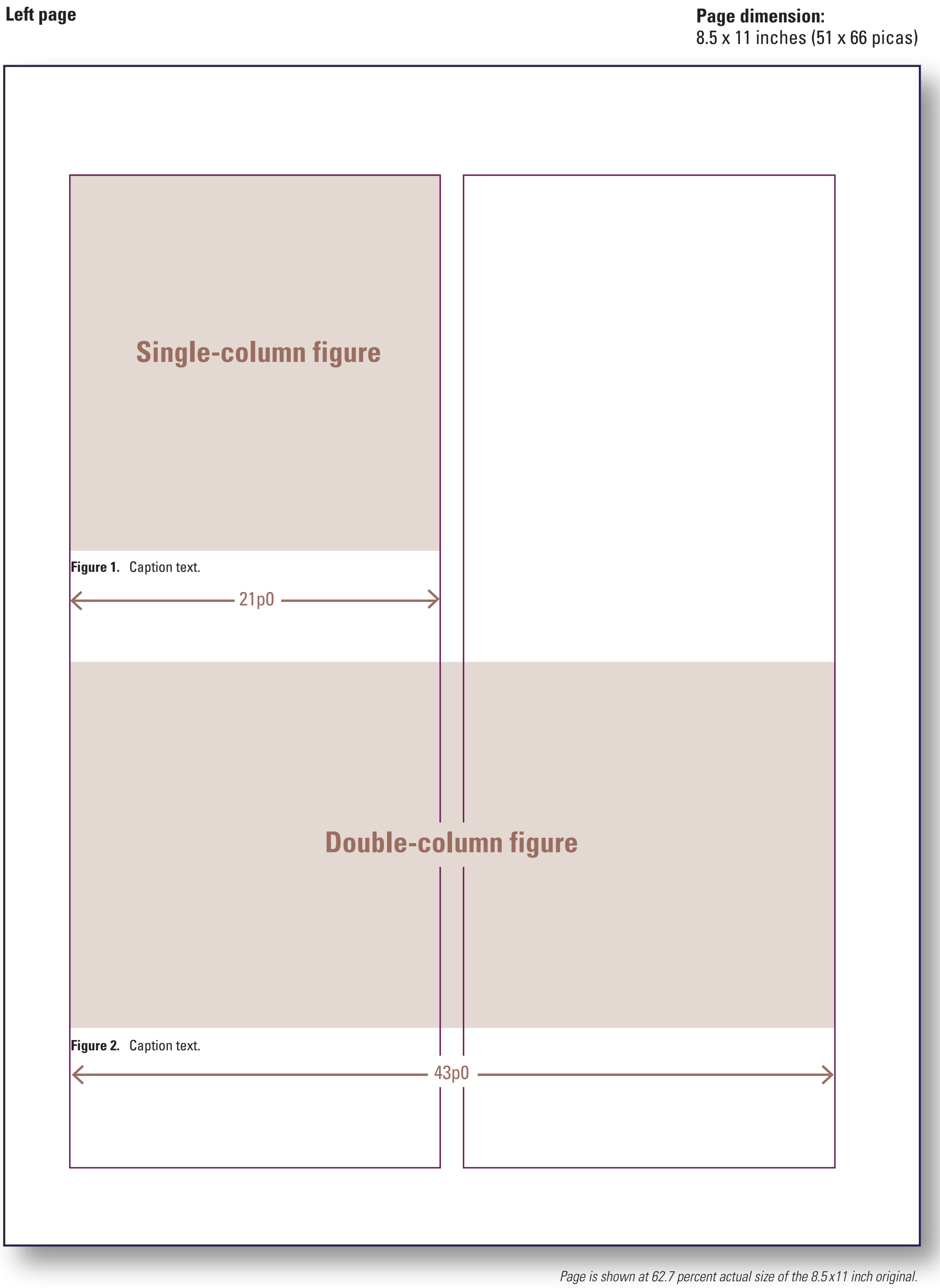
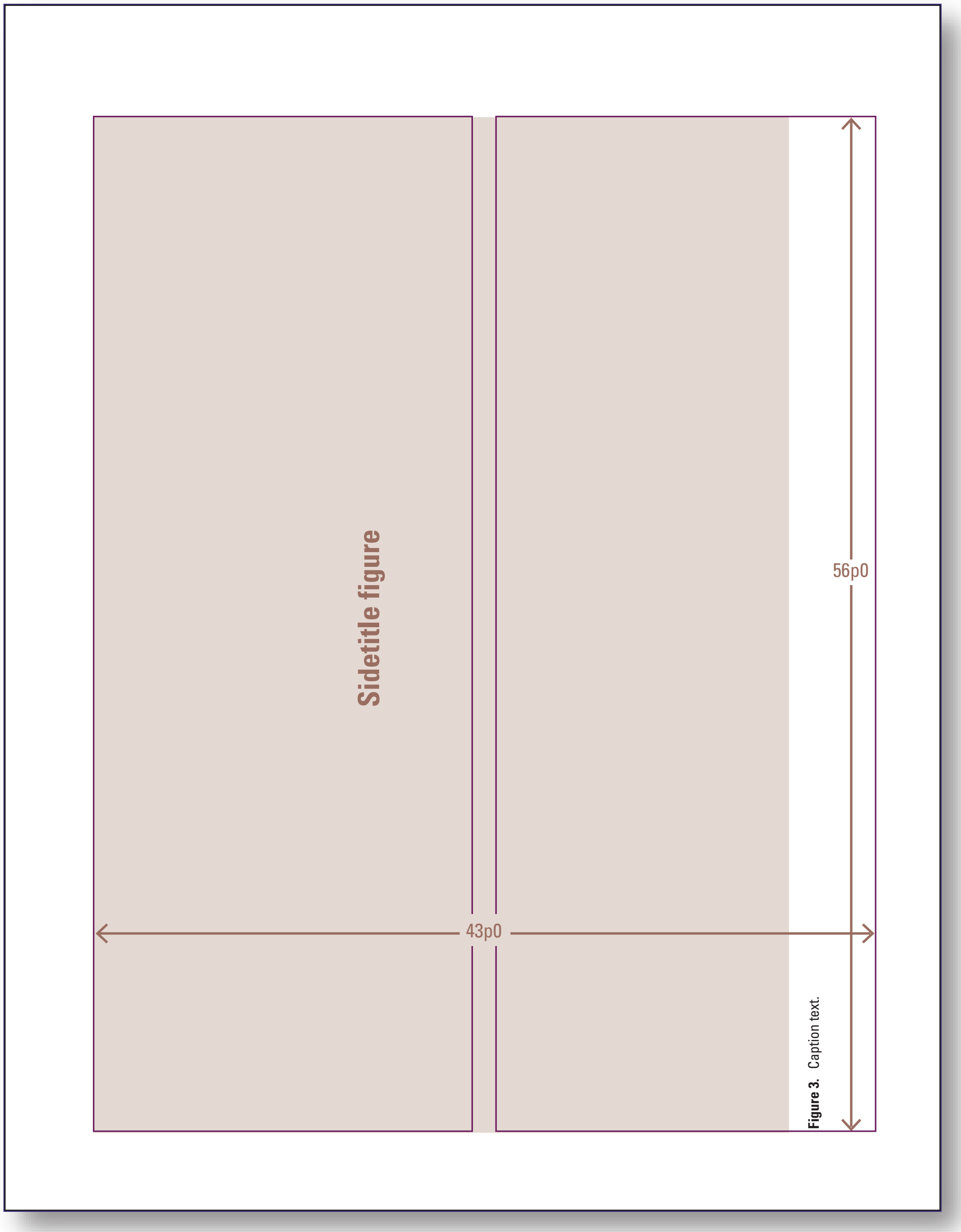


Figure 74. Width dimensions for single-column and double-column figures that have a portrait (bottom-title) orientation. The width of a figure may fill a single column (21 picas), a double column (43 picas), or any size in between, depending on the detail and complexity of the information being portrayed. p, pica.

Page dimension:
8.5 x 11 inches (51 x 66 picas)

Right page



Page is shown at 62.7 percent actual size of the 8.5x11 inch original.

Figure 75. Maximum dimensions for a figure that has a landscape (sidetitle) orientation are 56 by 43 picas (p).

Multipart Figures

Labeling Multipart Figures

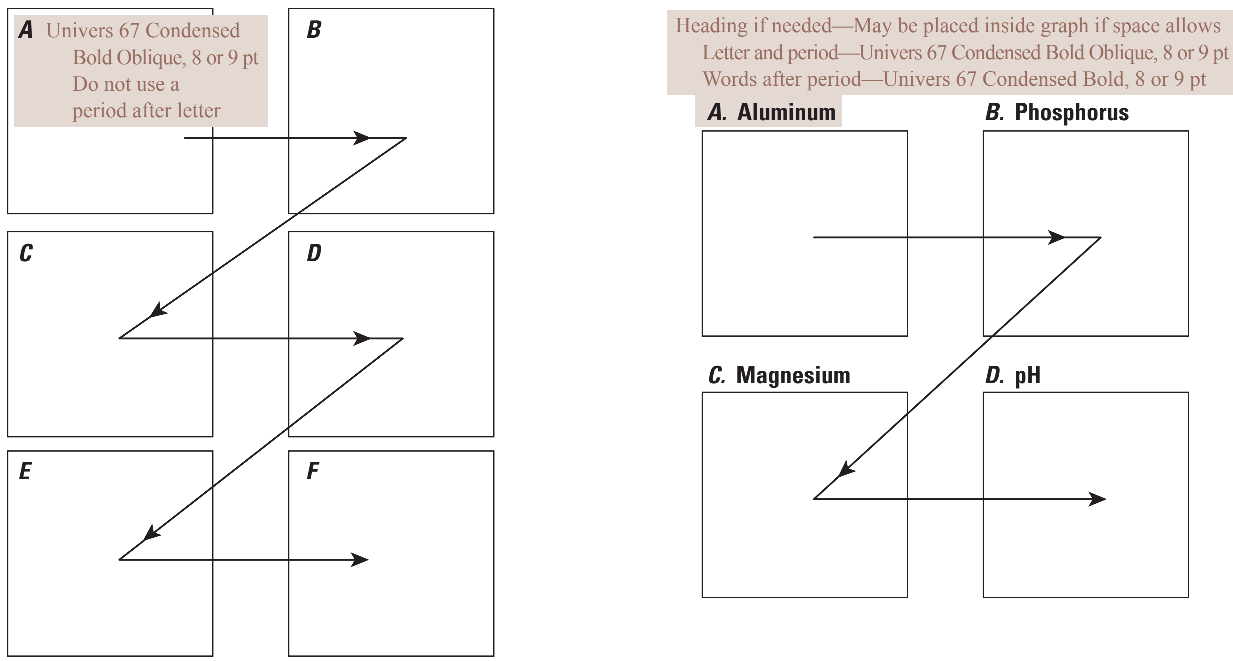


Figure 76. The individual parts of a multipart figure should be labeled horizontally and from top left to bottom right.

Example of a Multipart Figure

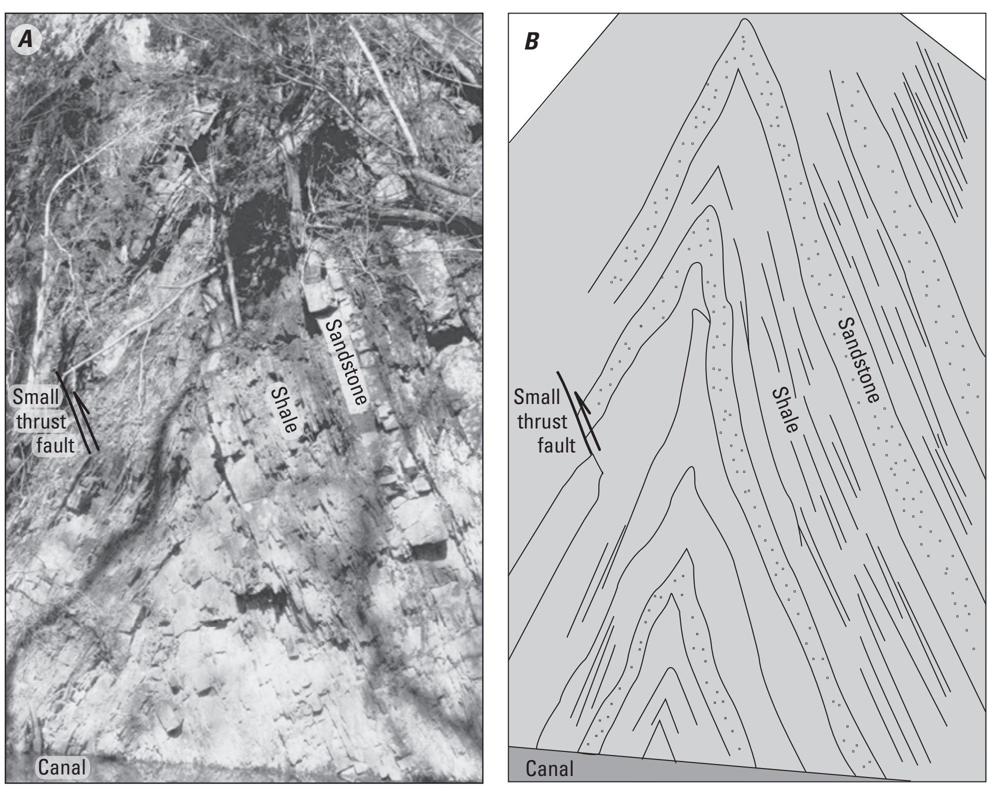


Figure 77. *A*, Photograph of a tight, upright anticline with a few labels. *B*, A drawing of that photograph with carefully rendered lines and patterns interpreting what is shown in the photograph. Labels must be carefully placed so as not to obscure what is being shown in the photograph.

Structures in the Upper Devonian Brallier Shale near the village of Little Orleans, Md. Figure modified from Southworth and others (2008).

“Zooming-In” Figures

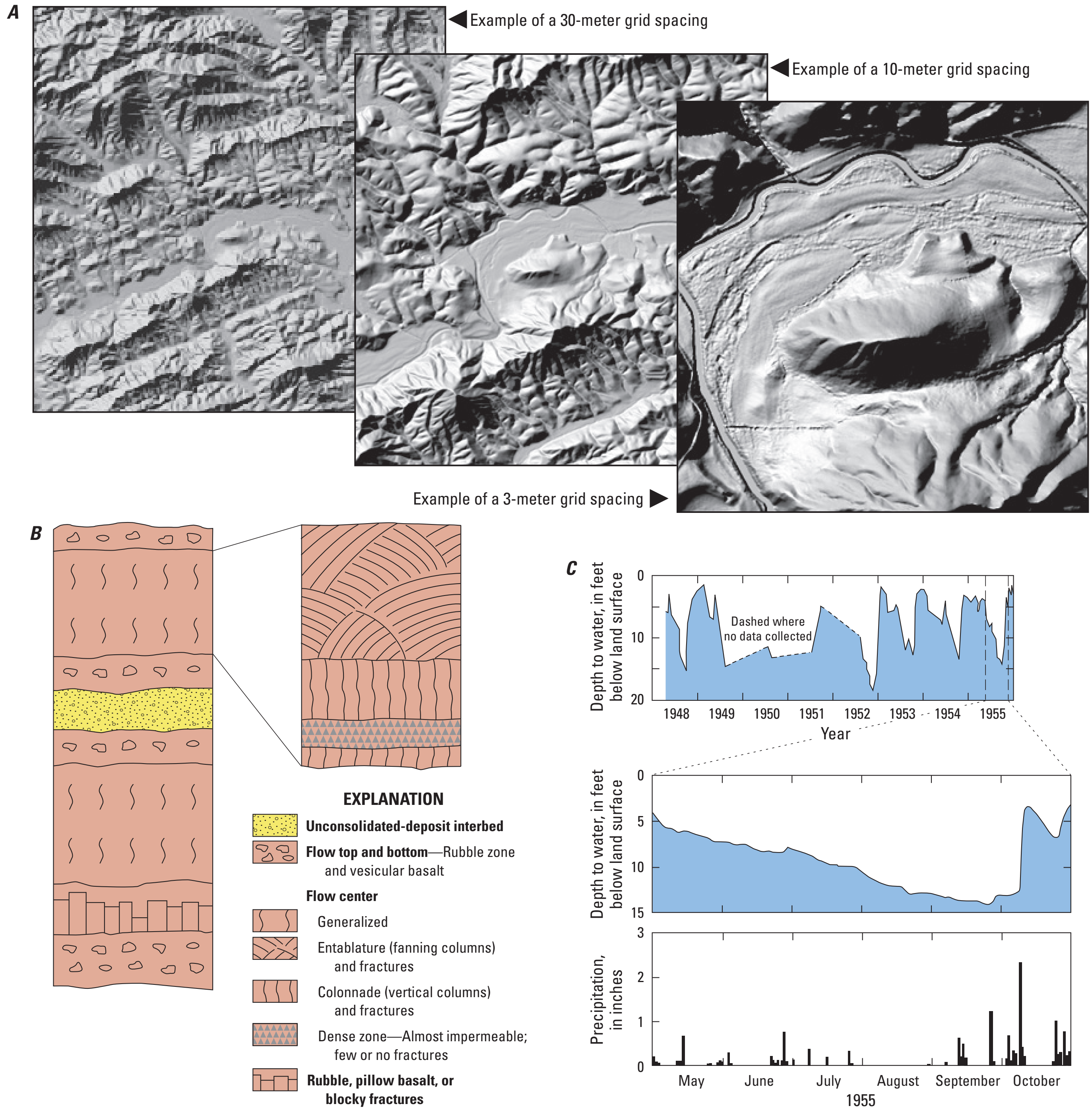


Figure 78. Images, columnar sections, and graphs illustrating the concept of "zooming in," going from general, or small scale, to more detailed, or large scale. Although many patterns are shown in the FGDC Standard, the patterns used in *B* for entablature, colonnade, and dense zone (among others) are not. Therefore for this illustration, patterns were created by the illustrator and are fully explained in the figure explanation. The bottom two graphs in *C* are stacked so that the same parameter (months and year) can be used for the *x*-axis caption. Also because there is room, the names of the months are spelled out.

A, Shaded-relief images of an area in North Carolina derived from the three resolutions available in the National Elevation Dataset. Figure modified from Gesch and others (2009).

B, Rubble zones and vesicular basalt at the top and the bottom of a flow provide open space for storage and movement of water. Figure modified from Whitehead (1994, fig. 44).

C, Water levels in aquifers near the Pacific Coast respond to variations in rainfall, particularly during the months of September and October. Figure modified from Whitehead (1994, fig. 16).

Figure-Ground Organization

By employing the concept of figure-ground organization, a viewer can look at an illustration and easily distinguish between the main figure and the less distinct, amorphous background around it. In its basic sense, figure-ground refers to the cognitive ability in all of us to separate contrasting elements—dark from light, black from white (Robinson and others, 1995).

Figure-ground is probably best known by the classic vase-face figure (shown below). When first viewing this figure, your eyes will probably alight on one of the curvy lines. If your eyes travel inward from this line, you'll perceive the vase; if your eyes travel outward from this line, you'll perceive the profiles of the two faces. Note that this figure does not portray to you what is more important; therefore, you do not know what part is the figure and what part is the background.

The separation of figure-ground is automatic; it is a natural and fundamental characteristic of visual perception and is therefore a primary component in graphic design. Distinguishing land from water is an example of figure-ground organization.

In figure 79*A*, a line wanders across a field of white, separating it into two areas. The wiggly line looks like a coastline. If it is, which area is land and which area is water? If the area looks familiar, this may not be difficult to ascertain. If you are familiar with general physiographic characteristics, such as branching tributaries, it may not be difficult, but it is still ambiguous.

In figures 79*B* and 79*C*, shading has been added and two areas are clearly defined, but the question remains—which area is land and which area is water?

In figure 79*D*, there is very little ambiguity left because of the addition of labels (States and water bodies) and county boundary lines. The land clearly emerges as the figure and the water, the background.

A

B

C

D

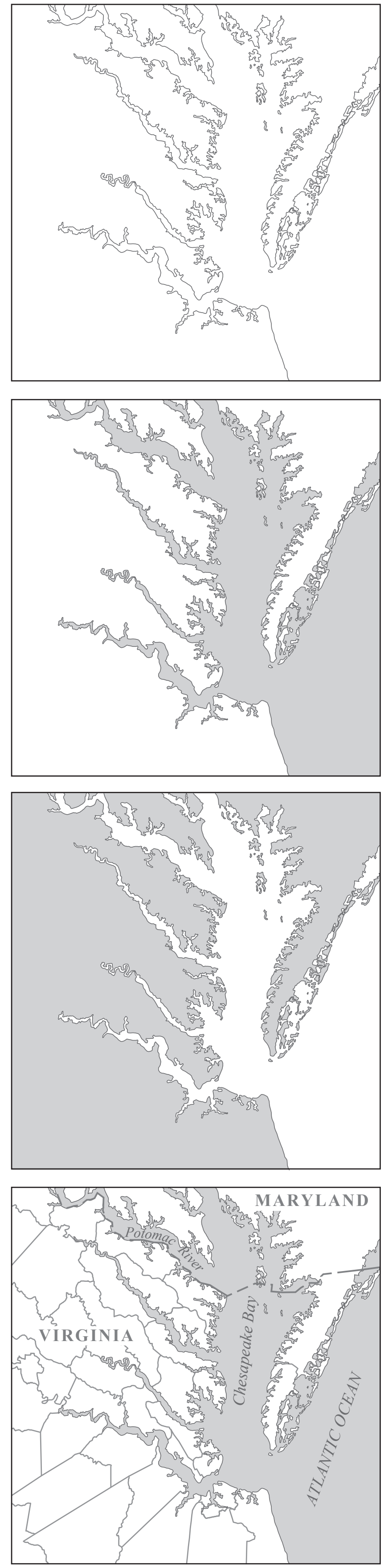
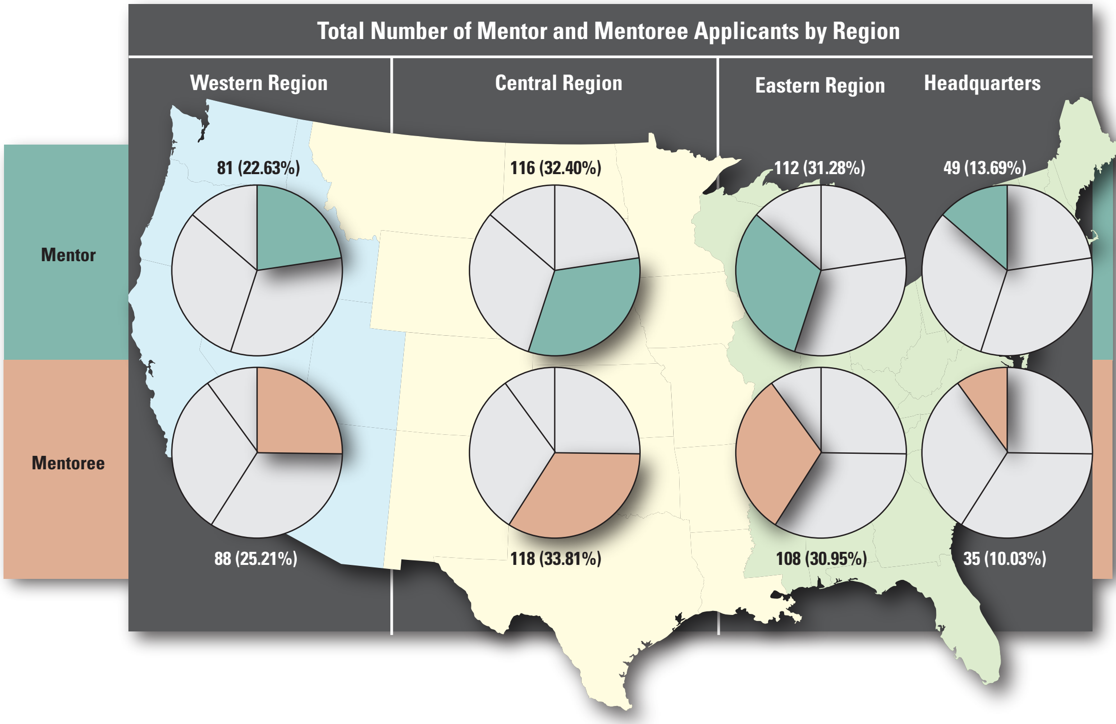


Figure 79. Four maps showing how the figure (land) emerges from the background (water).

Coordinated Color Palette



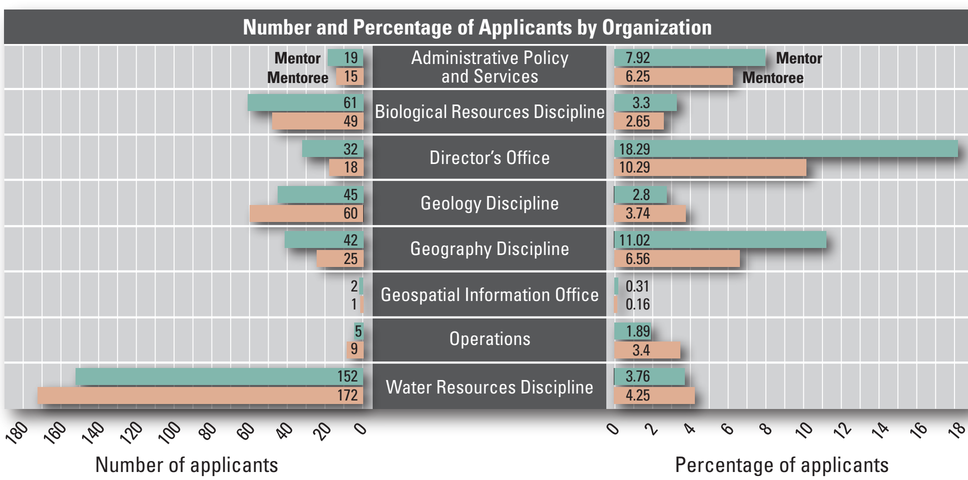
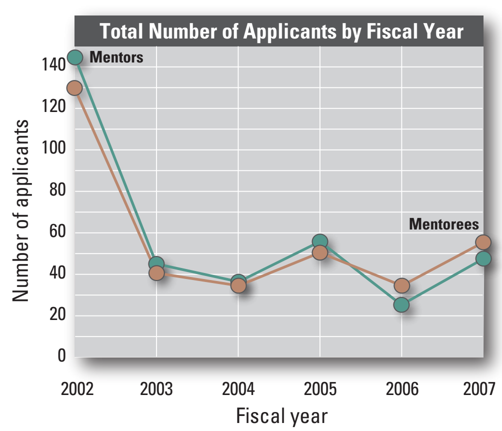


Figure 80. Three illustrations showing the use of a coordinated color palette have been excerpted from a six-page Fact Sheet that describes the mentoring program at the USGS. The Fact Sheet was designed with the general public in mind. Green represents information that relates to mentors, and brown represents information that relates to mentorees. In the Fact Sheet, variations of these greens and browns are used for the banner, headings, and neatlines surrounding side-bar information. The "%" symbol is used here, but be aware that if the symbol is too small, it is not easy to read. Although the use of ticks is preferred over grid lines, in two of these illustrations, "drop-out" grid lines contribute immensely to readability. Figures modified from Miller and Clarke (2007).



Examples of Miscellaneous Illustrations and Figures

Simple Illustrative Diagrams

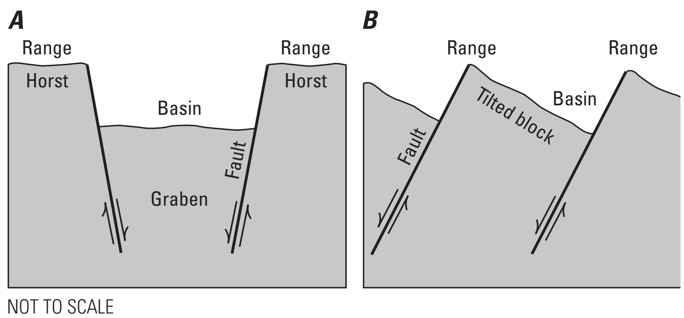


Figure 81. Simple diagram showing all features labeled in the figure or explained in the figure caption (for example, the paired arrows), eliminating the need for a separate explanation. Type specifications for maps and graphs were followed (see table 1). Notice that the placement of the type assures the immediate identification of each feature in the figure (for example, "fault" and "tilted block").

The alternating basins and ranges that characterize the topography of the Basin and Range physiographic province were formed during the past 17 million years by the gradual movement along faults. *A*, Horst and graben blocks of the Earth's crust. *B*, Tilting of blocks of the Earth's crust. Arrows indicate relative direction of movement of rocks on both sides of the faults. Figure modified from Robson and Banta (1995, fig. 33).

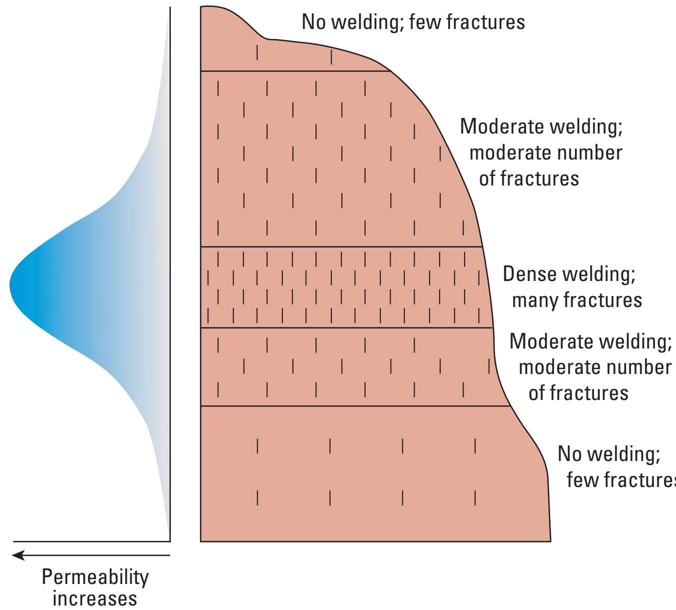


Figure 82. Simple schematic diagram using a gradient blend to show increasing permeability.

The density of fractures determines the permeability in tuffaceous silicic volcanic rocks that form many of the volcanic- and sedimentary-rock aquifers. Figure modified from Whitehead (1994, fig. 39).

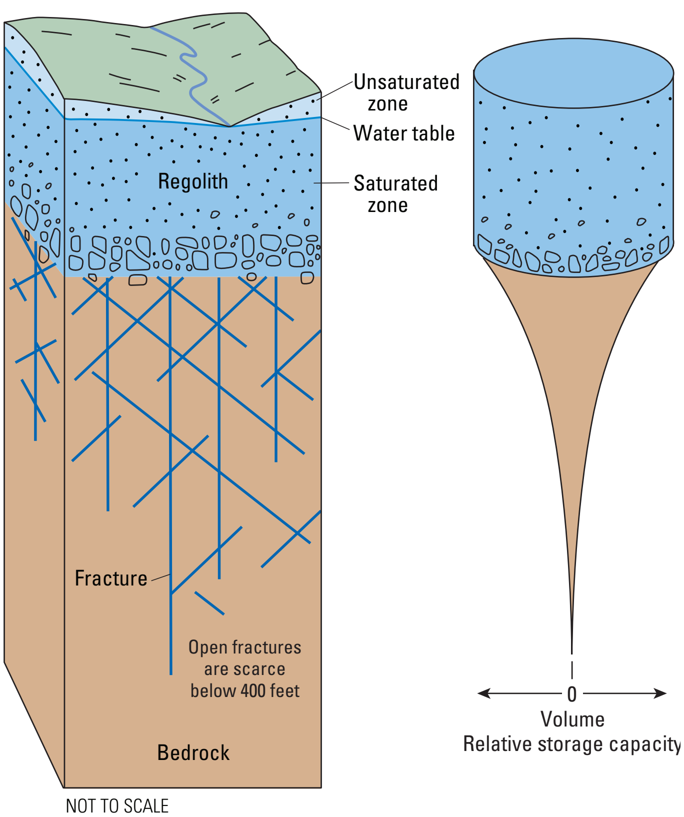


Figure 83. A well-crafted schematic diagram of a complicated concept can be understood at a glance.

The regolith—or layer of weathered rock material, soil, and alluvium—overlies fractured crystalline bedrock. Most of the water is stored in the more porous regolith and percolates downward into the interconnected fractures. The regolith has 20 to 50 times the water storing capacity of the bedrock. Figure modified from Miller (1990, fig. 90).

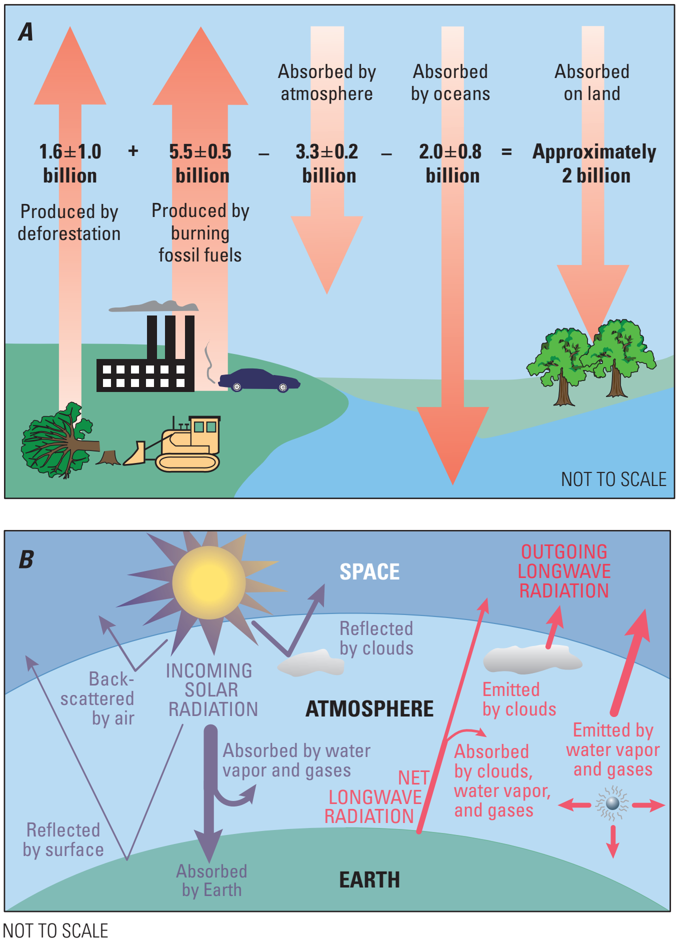


Figure 84. Two examples of schematic (cartoon-like) figures using clip art and bright, bold colors to draw the reader in. Colors in this type of illustration are used for effect and do not represent age or type of unit, geologic or hydrogeologic. Setting words in uppercase is generally discouraged because capital letters are hard to read, but in *B*, note that the text identifying the type of radiation is shown in all caps and accompanying explanatory text is shown in caps and lowercase, thus establishing a hierarchy. Arrows are used only to indicate direction—not as leaders.

A, The global CO_2 (carbon dioxide) budget is defined as the balance of CO_2 as it is transferred to and from the atmosphere. Units are in metric tonnes of carbon per year. Budget figures shown here are for the 1980s. *B*, The greenhouse effect, which is part of the Earth's climate system, maintains temperatures far warmer than would be expected from direct solar heating. Most of the incoming solar radiation (short wavelength, shown in purple) is absorbed and converted to long wavelength radiation (shown in red), at or near the Earth's surface. Figures modified from Markewich and others (1997).

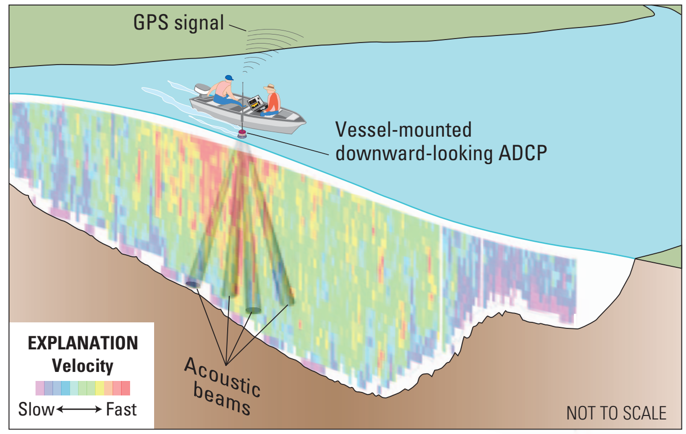


Figure 85. Schematic diagram demonstrating how actual data (in this case, a velocity contour plot of an ADCP transect, visible on the block face) and art can be combined in one figure. The single entry in the explanation shows at a glance the relative velocity of the water in the stream at any given point. ADCP, Acoustic Doppler current profiler; GPS, global positioning system.

Acoustic Doppler current profilers, attached to manned boats, are replacing traditional mechanical current meters for measuring streamflow. Figure modified from Gotvald and Oberg (2008).

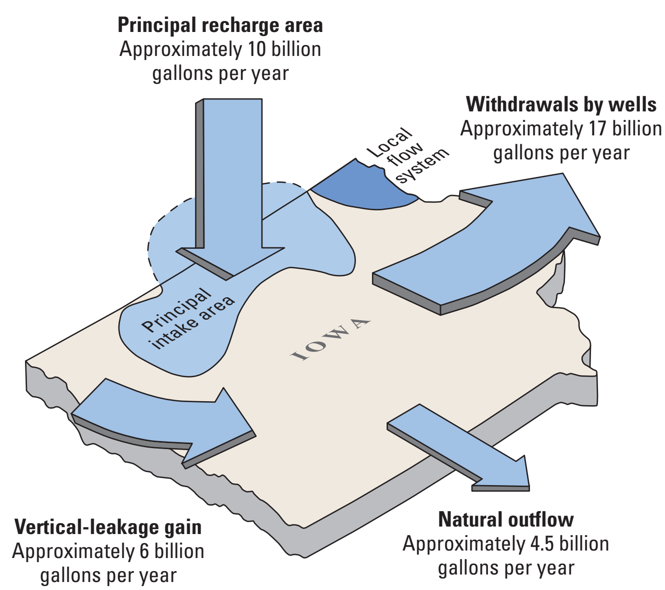


Figure 86. Schematic diagram showing the use of arrows of slightly different sizes to indicate relative amounts of water inflow and outflow in Iowa.

Estimates of the principal inflow and outflow of water to the St. Peter-Prairie du Chien-Jordan aquifer in the State of Iowa. Comparison of recharge to and discharge from the aquifer indicates a deficit of 5.5 billion gallons of water per year. The net regional water-level decline is 1.8 to 2.4 feet per year. Figure modified from Olcott (1992, fig. 120).

Illustrative/Art Type Figures

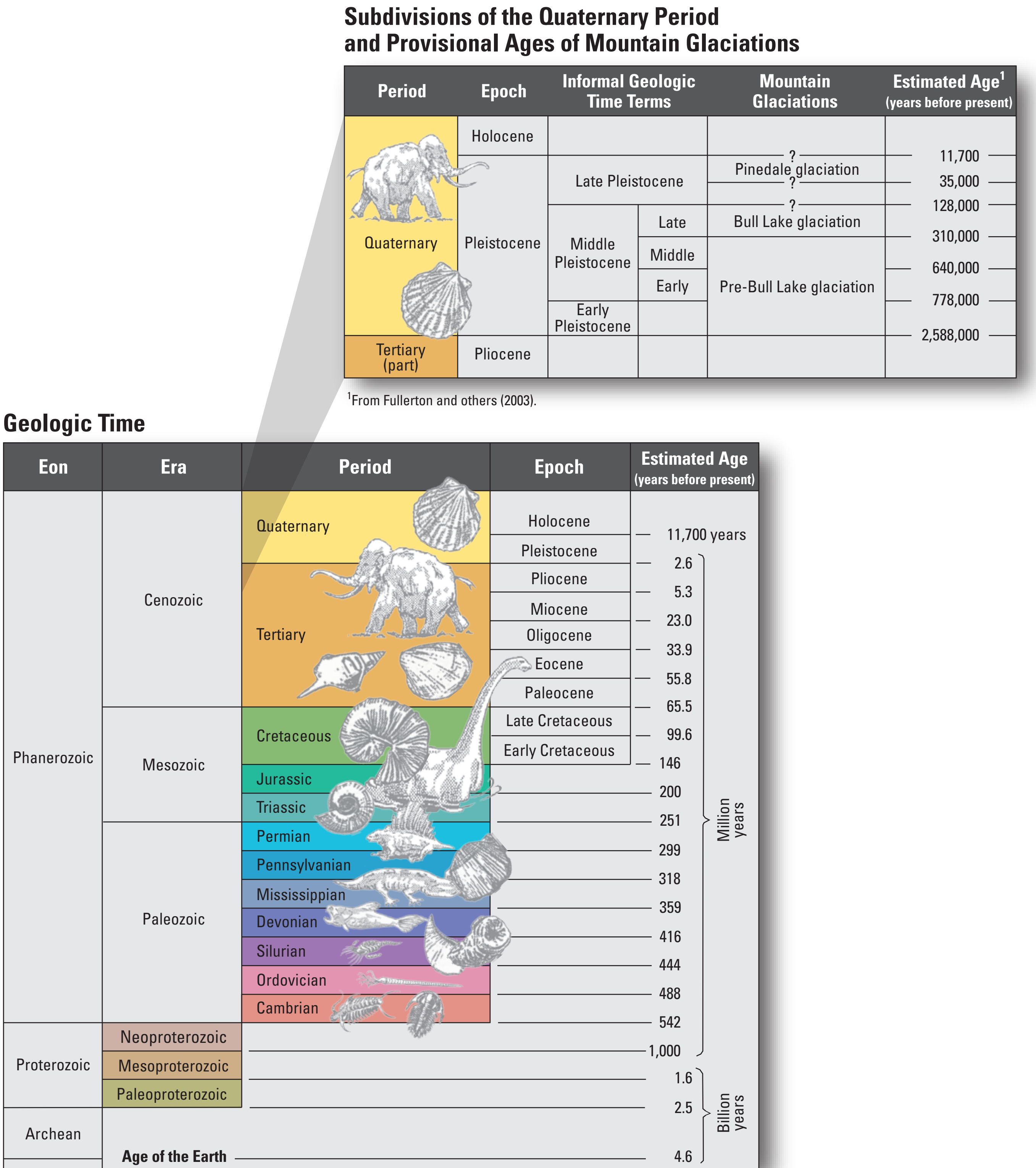


Figure 87. Charts showing subdivisions of the Quaternary Period and provisional ages of mountain glaciations (above) and geologic time (below). Instead of two lines, a tunnel of gray was used to show the relation between the two parts of the figure. Note the use of "drop-out" or "reverse" type for the headings. Colors for age units follow those specified in U.S. Geological Survey (2006; see figure 8 (p. 19) of these standards). Figure modified from Madole and others (2005) and ages updated per U.S. Geological Survey Geologic Names Committee (2010).

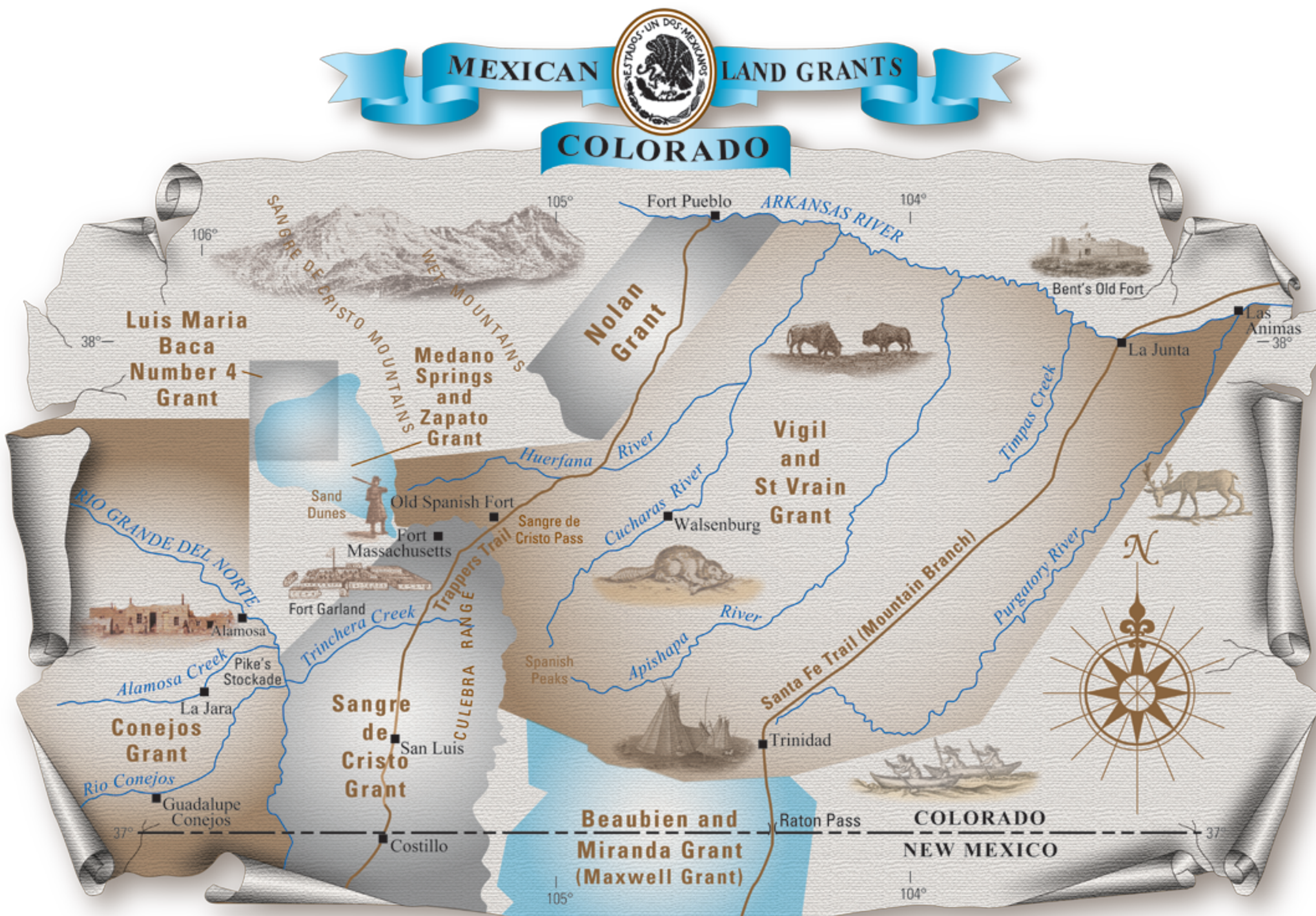
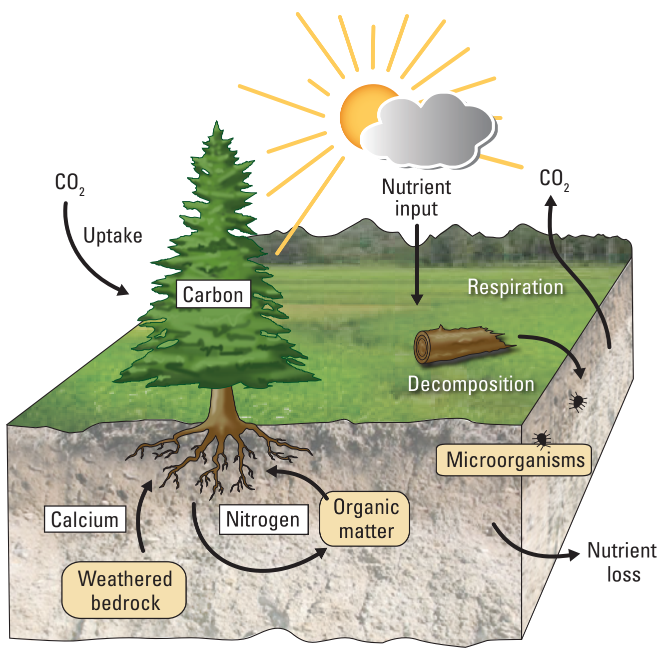


Figure 88. One of a series of historical trail maps prepared in cooperation with The Denver Public Library. Upon closer inspection, it can be seen that the background image has been manipulated so that it looks like a piece of parchment. All fonts shown in this figure match those specified in these standards. The illustrator, however, has taken more freedom with point size and case. Note the embellished, compass-like north arrow and the use of carefully placed screened images throughout the figure.

Extent of the Mexican Land Grants in what is now southern Colorado and northern New Mexico, as of June 21, 1860. Figure modified from Scott (2001).



NOT TO SCALE

Figure 89. Block diagram showing how original artwork can be superimposed on a photograph. The illustrator effectively used both reverse type (white) and standard type (black). Additionally, the illustrator grouped text visually by using elliptical, tan-colored and rectangular, white-colored shapes. Arrows are used only to indicate direction—not as leaders.

Carbon, nitrogen, calcium, and other key nutrients are transferred from plant to soil to air and back to plant again through processes such as uptake, respiration, and decomposition. Figure modified from Beldin and Perakis (2009).

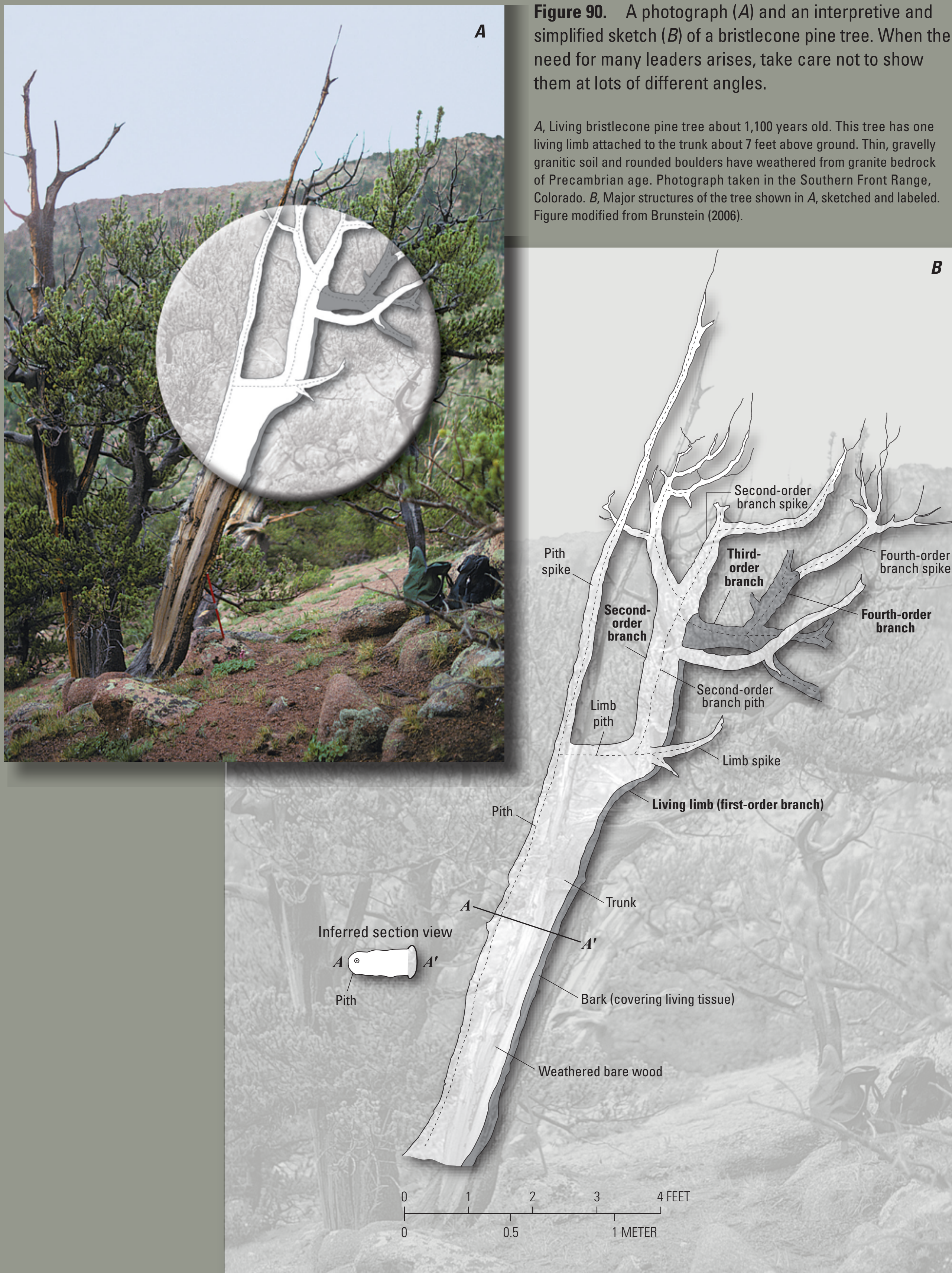
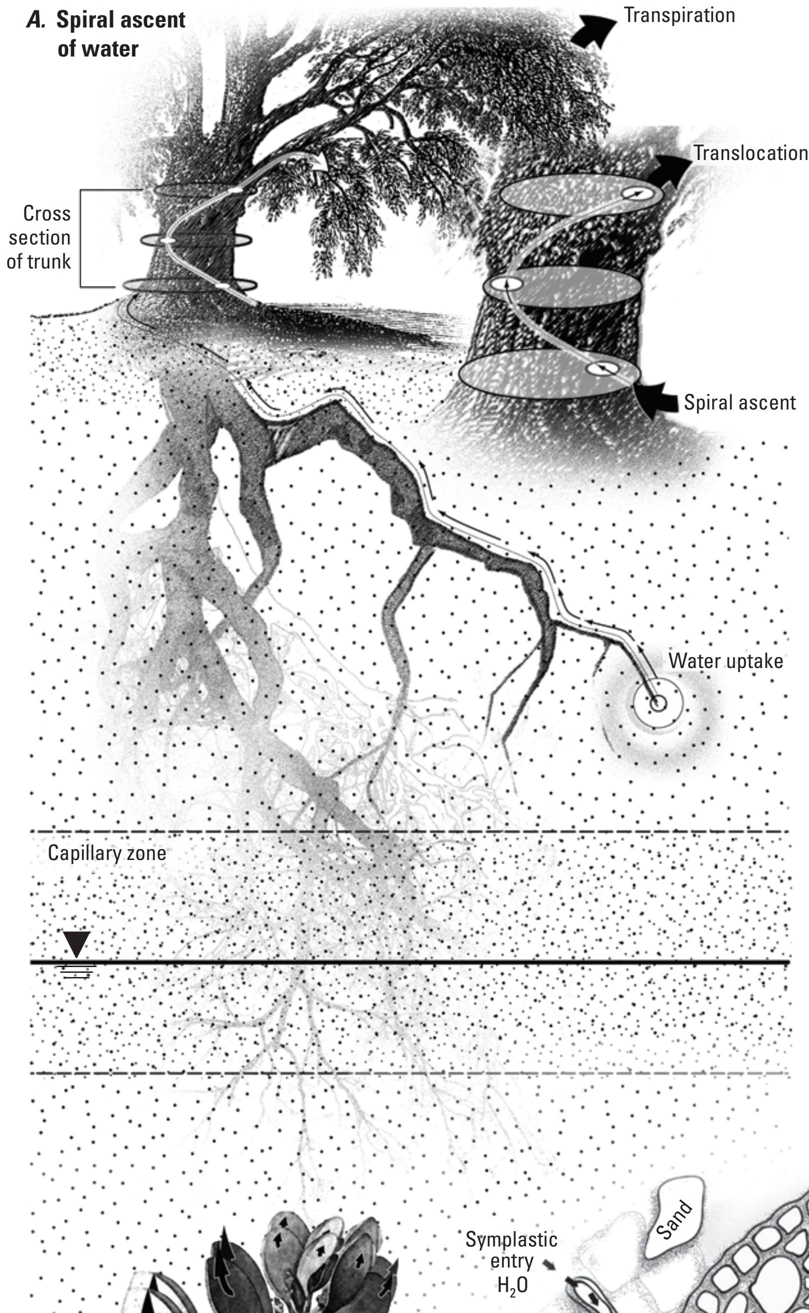
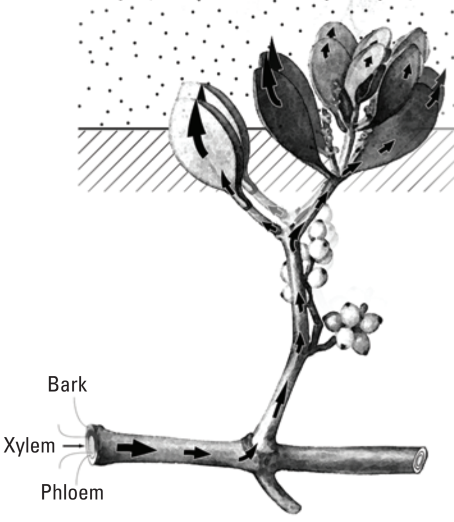


Figure 90. A photograph (*A*) and an interpretive and simplified sketch (*B*) of a bristlecone pine tree. When the need for many leaders arises, take care not to show them at lots of different angles.

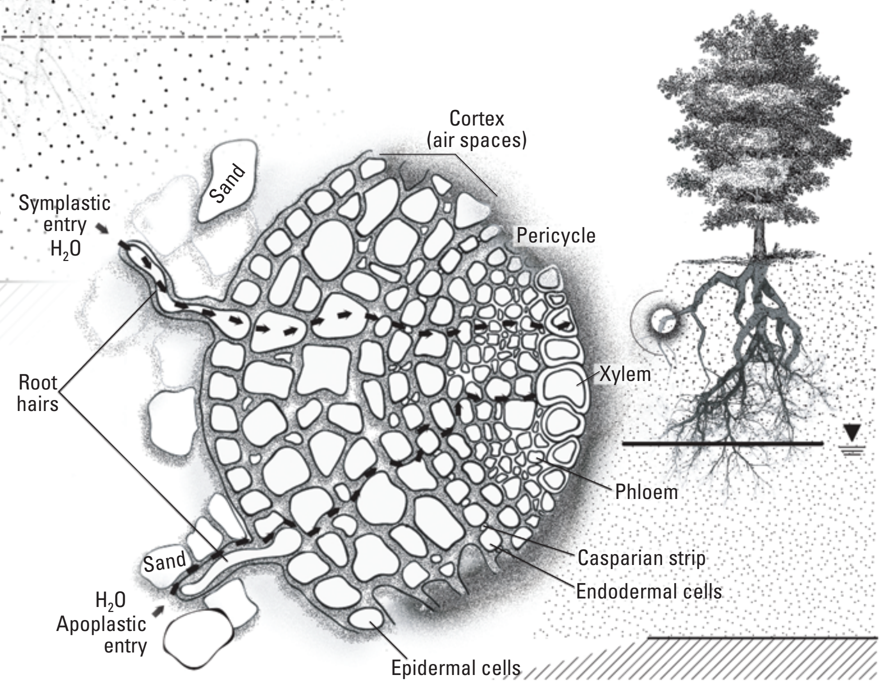
A, Living bristlecone pine tree about 1,100 years old. This tree has one living limb attached to the trunk about 7 feet above ground. Thin, gravelly granitic soil and rounded boulders have weathered from granite bedrock of Precambrian age. Photograph taken in the Southern Front Range, Colorado. *B*, Major structures of the tree shown in *A*, sketched and labeled. Figure modified from Brunstein (2006).



A. **Spiral ascent of water**



B. **Mistletoe**



C. **Entry of water into vascular system**

Figure 91. Diagrams—in the style of 19th-century engravings—showing how plants obtain water and nutrients. These illustrations were created for a phytoremediation textbook and were initially hand drawn. The illustrator then scanned these "engravings" to create more easily editable digital raster graphics. Using Adobe Photoshop effects and Adobe Illustrator pen techniques, the illustrator was able to enhance those features the author wished to emphasize in order to create the illustrations shown here. Text, lines, and arrows were added using Adobe Illustrator. Figures modified from James E. Landmeyer (USGS, written commun., March 2010).

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